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United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Research Triangle Park, NC 27711

EPA-452/R-95-001
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Air

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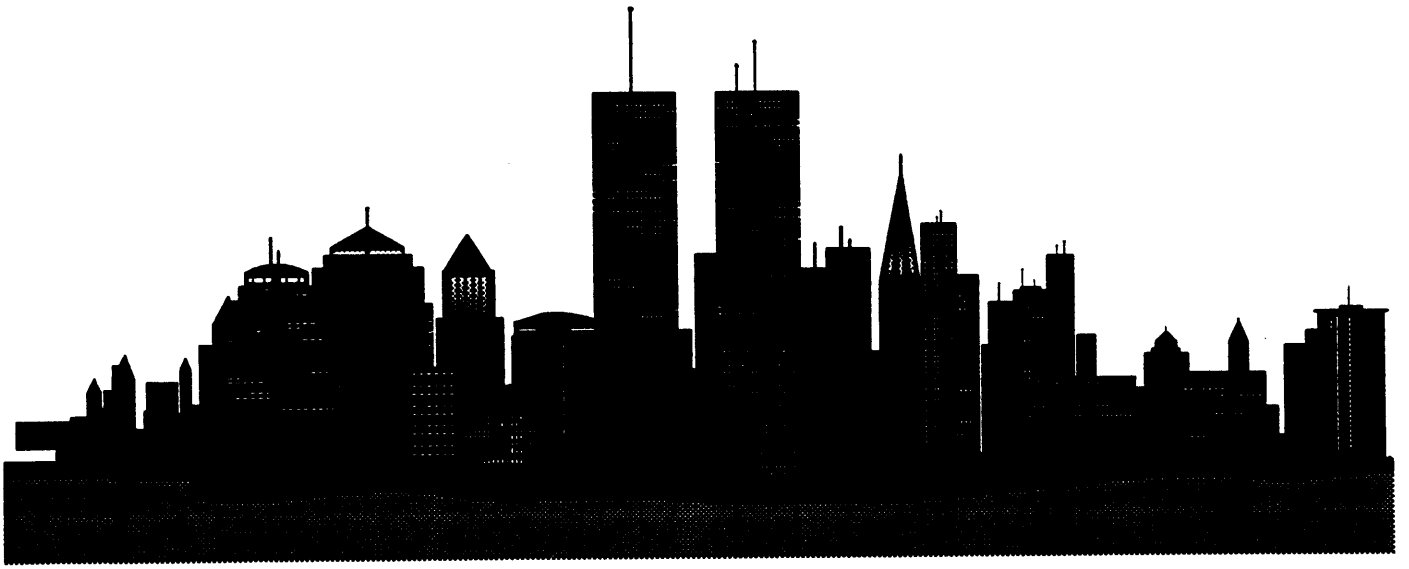
SUMMARY OF URBAN AIR TOXICS RISK ASSESSMENT SCREENING STUDIES TO SUPPORT THE URBAN AREA SOURCE PROGRAM



Office of Air Quality Clean Air OAQPS Planning and Standards

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SUMMARY OF URBAN AIR TOXICS RISK ASSESSMENT SCREENING STUDIES TO SUPPORT THE URBAN AREA SOURCE PROGRAM

U.S. ENVIRONMENTAL PROTECTION AGENCY

Office of Air and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

Table of Contents

List of Figures and Tables

Table

Table

Figure

Chapter 1
SUMMARY

Under Section 112(k) and 112(c)(3) of the Clean Air Act Amendments of 1990, the U. S. Environmental Protection Agency (EPA) must develop and implement a national strategy to control hazardous air pollutants (HAPs) from area sources. The national strategy must identify 30 or more HAPs presenting the greatest threat to public health in large urban areas and identify regulatory actions to achieve significant reductions in area source emissions of these HAPs. Subsequent to publication of this strategy in 1995, EPA must establish regulations to implement this strategy by the year 2000.

This report summarizes the air toxics exposure and risk assessment screening studies conducted in the last decade. It includes studies summarized in the 1990 EPA report entitled Cancer Risk From Outdoor Exposure to Air Toxics[1] and includes more current studies performed since 1990. Generally, the studies summarized in this report represent exposure and cancer risk assessments based on dispersion modeling of emissions inventory data. Some of the studies represent assessments based on ambient monitoring data. Some also address noncancer effects, although generally to a limited extent. This report is one of several independent approaches to identify HAPs and area sources in the national strategy. As such, this report does not select specific HAPs for inclusion in the national strategy.

Tables 1-1 through 1-5 summarize the results of this analysis. Table 1-1 presents the areawide cancer incidence associated with each study HAP and also rank orders the study HAPs by areawide cancer incidence. Table 1-2 presents the areawide cancer incidence associated with each source category and also rank orders the categories by areawide cancer incidence. For inter-city comparison purposes, cancer incidence is normalized per million population residing in each study area. Areawide, annual excess cancer incidence reported in the eleven studies ranges from about 0.2 to 17 cases per year per million population, with values between 1 and 5 most common. The HAPs consistently ranking highest are polycyclic organic matter (POM), benzene, hexavalent chromium, formaldehyde, 1,3-butadiene, ethylene oxide, arsenic, and cadmium. Gasoline vapor also ranked relatively high in some studies, but is not a listed HAP under Section 112.

None of the cancer screening studies distinguishes between major and area source categories per the Section 112(a) definition, which is based on an emission threshold of 10 tons/year (TPY) of any single HAP or 25 TPY of any combination of HAPs. This is because most of the studies were conducted before enactment of the Clean Air Act Amendments of 1990, wherein this major/area source distinction became relevant within the context of Section 112. Hence, area sources of HAPs could not clearly be identified or ranked by cancer incidence based on these study results, pursuant to this 10/25 TPY threshold.

Table 1-3 presents cancer incidence averaged across all eleven screening studies, as well as the maximum and minimum reported incidence and the number of studies reporting an incidence for a particular HAP. Table 1-4 presents this same information, but by source category.

Table 1-5 summarizes the HAPs indicated as potential concerns based on noncancer health endpoints, from three screening studies. Because of different endpoints identified in each study for each pollutant, no quantitative measure of noncancer serves as a convenient common denominator for comparison purposes. Because of the problem of comparing differing noncancer endpoints, and

because of the considerable uncertainty in these noncancer screening studies, no ranking of HAPs is made in this report. Rather, the HAPs are simply identified in Table 1-5 for which each respective study felt there may be some cause for concern. Many of these HAPs are also carcinogens.

Inclusion of any study results herein does not indicate acceptance or validation of the study methodology or data by EPA. The limitations associated with any of the studies are presented in this report, and will be considered in the development of the national area source strategy. Clearly, some of the methods employed in these studies vary widely because of age and the data and resources available when a study was performed. No attempt was possible in this report to identify and correct for any methods or data that may have changed since the original study was carried out.

Table 1-1. Normalized Cancer Incidence by Pollutant for Each Study

(excess annual cancer cases per million population within study area)

HAP	Five City-3*		IEMP-Kanawha Valley-4		IEMP-Philadelphia-5		IEMP-Santa Clara-6		South Coast-8		Southeast Chicago-9		Twin City-17		Southwest Chicago-10		Modeled data: IEMP-Baltimore II-7		Monitored data: IEMP-Baltimore II-7		Houston-11		Detroit-12	
1,2-Dibromoethane			(11)	0.01					(4)	0.002	(13)	0.002	(10)	0.005	(20)	0.001	(10)	0.003					(14)	0.002
1,2-Dichloroethane	(8)	0.05	(14)	0.004	(1)	0.08					(13)	0.002	(13)	0.0008	(20)	0.001	(10)	0.003	(5)	0.2				
1,3-Butadiene	(4)	0.9	(2)	4.4							(5)	0.3	(2)	0.3	(1)	0.7					(1)	0.9	(2)	0.2
Acetaldehyde													(17)	0.000001										
Acrylamide															(26)	0.00001								
Acrylonitrile			(3)	1.9									(15)	0.00002	(22)	0.0006							(22)	0.000003
Arsenic, inorganic	(7)	0.07	(6)	0.2							(9)	0.05	(6)	0.02	(8)	0.04	(3)	0.1	(6)	0.1			(8)	0.02
Asbestos (friable)															(17)	0.005							(8)	0.02
Benzene	(5)	0.5	(5)	0.4	(5)	0.008	(1)	0.2	(1)	0.8	(6)	0.2	(4)	0.1	(7)	0.1	(3)	0.1	(3)	1.1	(3)	0.04	(8)	0.02
Benzo (a) pyrene																			(10)	0.04				
Beryllium													(14)	0.0003	(30)	0.0000009							(8)	0.02
Cadmium	(15)	0.009	(8)	0.03					(3)	0.04	(10)	0.03	(7)	0.01	(14)	0.009	(7)	0.04	(11)	0.03			(13)	0.005
Carbon tetrachloride	(10)	0.03									(6)	0.2			(5)	0.2			(9)	0.05			(2)	0.2
Chloroform	(13)	0.01	(3)	1.9											(14)	0.009			(4)	0.5			(21)	0.00001
Chromium (VI)	(2)	1.0							(2)	0.7	(2)	0.5	(2)	0.3	(2)	0.6	(2)	0.3	(2)	1.7			(5)	0.05
Coke oven emissions											(1)	0.9			(5)	0.2							(2)	0.2
Dichloroethene			(11)	0.01											(22)	0.0006								
Dioxins											(16)	0.0004			(18)	0.003							(6)	0.04
Epichlorohydrin															(26)	0.00001							(22)	0.000003
Ethylene oxide	(6)	0.1	(1)	8.4							(11)	0.02	(7)	0.01	(10)	0.03							(22)	0.000003
Formaldehyde	(2)	1.0									(2)	0.5	(4)	0.1	(4)	0.5	(6)	0.06			(2)	0.3	(1)	0.4
Gasoline vapor	(8)	0.05			(2)	0.06					(8)	0.1			(8)	0.04							(12)	0.01
Hexachlorobenzene															(11)	0.02								
Methyl chloride															(24)	0.0002					(4)	0.01		
Methylene chloride	(12)	0.02	(7)	0.04									(10)	0.005	(14)	0.009	(3)	0.1	(6)	0.1			(18)	0.0003
Perchloroethylene	(10)	0.03	(8)	0.03	(3)	0.02					(15)	0.001	(10)	0.005	(12)	0.01	(8)	0.03	(1)	3.4			(17)	0.0007
Polychlorinated biphenyls															(29)	0.000004							(18)	0.0003
Polycyclic organic matter	(1)	1.6	(8)	0.03							(4)	0.4	(1)	1.8	(2)	0.6	(1)	1.3					(6)	0.04
Propylene dichloride																			(6)	0.1				
Propylene oxide															(28)	0.000007								
Styrene													(16)	0.000005	(25)	0.00006							(18)	0.0003
Trichloroethylene	(13)	0.01	(11)	0.01	(4)	0.01					(12)	0.008	(7)	0.01	(12)	0.01	(9)	0.02	(12)	0.02			(15)	0.001
Vinyl chloride	(16)	0.0008													(19)	0.002							(15)	0.001
Study Total		8.4		17.4		0.2		0.2		1.8		3.2		2.7		3.1		2.1		7.3		1.3		1.2

Caveat: Estimates of cancer incidence in these screening studies are not absolute predictions of cancer occurrence and are intended to be used in a relative sense only. See Section 2.5 for a discussion of the many assumptions and uncertainties associated with these estimates.

Notes:

(1) Numbers in parentheses represent the ordinal ranking of pollutants by cancer incidence for each study.
(2) Blank cells indicate a pollutant was not analyzed for that particular study.
(3) If multiple pollutants have the same normalized cancer incidence they are assigned the same ordinal ranking and subsequent numbers are assigned their true ordinal rank. For example, if two pollutants have an ordinal rank of 4, the next pollutant would be assigned an ordinal rank of 6.
(4) Gasoline vapor is not on the 189 HAPs list, it is included in this table because several studies showed relatively high incidence from gasoline vapor.

* Source of information by reference number.

Contains Sources Category for these studies. Will be useful.

Source Category									Modeled data: Twin City-17		Southwest Chicago-10		IEMP-Baltimore II-7		Houston-11		Detroit-12	
Aircraft Engines											(4)	0.3						
Asbestos/Demolition											(20)	0.001						
Background Carbon Tetrachlorid									2		(6)	0.2					(2)	0.2
Barge Loading											(24)	0.00003						
Chemical Manufacturing									)1									
Chemical Users and Producers																		
Chrome Platers									.5	(3)	0.3	(2)	0.5					
Coal and Oil Combustion/Heatl												(14)	0.01	(3)	0.2		(6)	0.08
Commercial Incinerators										(5)	0.08							
Commercial Sterilization/Hospitc									01			(18)	0.007					
Cooling Towers									06			(8)	0.07					
Delaware River																		
Dry Cleaning												(17)	0.008	(8)	0.02			
Gasoline Marketing									.03			(11)	0.04	(10)	0.006			
Heating/Combustion									08	(4)	0.2	(12)	0.02	(5)	0.09			
Heating/Woodstoves									0.3	(2)	0.4	(22)	0.0007	(8)	0.02		(8)	0.001
Industrial Solvent Coating																		
Iron and Steel									1.0			(6)	0.2				(2)	0.2
Manufacturing Operations																	(7)	0.02
Motor Vehicles	(1)	2.7	(2)	0.7					0.6	(1)	1.6	(1)	0.8			(3)	0.003	(4)	0.1
Motor Vehicles/Diesel														(6)	0.08			
Motor Vehicles/Gasoline														(2)	0.7			
Municipal Waste Combustors					(9)	0.0005												
Municipal Waste Landfill												(22)	0.0007					
Nonferrous Smelters	(18)	0.01																
Nonroad Engines												(4)	0.3					
Other	(6)	0.1							(13)	0.004		(10)	0.06	(7)	0.05	(1)	1.1	(4)	0.1
Other Miscellaneous Area Sources									(13)	0.004	(6)	0.05	(12)	0.02			(4)	0.0002
Other Organic Evaporation	(15)	0.02			(7)	0.005												
Point and Other Stripping												(19)	0.002					
Pesticide Usage					(4)	0.01												
Petroleum Refining	(15)	0.02		(1)	0.05						(7)	0.03	(8)	0.07	(1)	1.0	(2)	0.2
Point Sources													(14)	0.01				
POTW's				(1)	0.05													
Refractories	(13)	0.03																
Secondary Formaldehyde Formation	(2)	0.6							(4)	0.4			(3)	0.4			(1)	0.5
Sewer Volatilization				(4)	0.01													
Solvent Use/Degreasing	(10)	0.04	(5)	0.05	(4)	0.01			(12)	0.007			(14)	0.01	(4)	0.1		
Specialty Steel	(21)	0.00006							(15)	0.002								
Surface Coating													(20)	0.001				
TSDF's									(17)	0.0007								
Unspecified Stationary Sources	(6)	0.1	(10)	0.0002	(8)	0.0002	(5)	0.007	(1)	1.0	(9)	0.02						
Waste Oil Combustion/Burning			(9)	0.005														
Study Total		5.3		16.9		0.2		0.2		1.6		3.1		2.7		3.0		2.3		1.3		1.2

Caveat: Estimates of cancer incidence in these screening studies are not absolute predictions of cancer occurrence and are intended to be used in a relative sense only. See Section 2.5 for a discussion of the many assumptions associated with these estimates.

NOTES:

(1) Numbers in parentheses represent the ordinal ranking of source categories by cancer incidence for each study.

(2) Blank cells indicate a source category was not analyzed for that particular study.

(3) If multiple source categories have the same normalized cancer incidence they are assigned the same ordinal ranking and subsequent numbers are assigned their true ordinal rank. For example, if two source categories have an ordinal rank of 4, the next highest source category would be assigned an ordinal rank of 6.

-Source of information by reference number

Table 1-3. Average Cancer Incidence by Pollutant Across Studies
(excess annual cancer cases per million population within study area)

HAP	Average Cancer Incidence	Maximum Cancer Incidence	Minimum Cancer Incidence	Number of Studies Reported
1,2-Dibromoethane	0.004	0.01	0.001	7
1,2-Dichloroethane	0.04	0.2	0.0008	8
1,3-Butadiene	1	4.4	0.2	7
Acetaldehyde	0.000001	0.000001	0.000001	1
Acrylamide	0.00001	0.00001	0.00001	1
Acrylonitrile	0.5	1.9	0.000003	4
Arsenic, inorganic	0.08	0.2	0.02	8
Asbestos (friable)	0.01	0.02	0.005	2
Benzene	0.3	1.1	0.008	12
Benzo (a) pyrene	0.04	0.04	0.04	1
Beryllium	0.007	0.02	0.0000009	3
Cadmium	0.02	0.04	0.005	9
Carbon tetrachloride	0.1	0.2	0.03	5
Chloroform	0.5	1.9	0.00001	5
Chromium (VI)	0.6	1.7	0.05	8
Coke oven emissions	0.4	0.9	0.2	3
Dichloroethene	0.005	0.01	0.0006	2
Dioxins	0.01	0.04	0.0004	3
Epichlorohydrin	0.000007	0.00001	0.000003	2
Ethylene oxide	1	8.4	0.000003	6
Formaldehyde	0.4	1	0.06	7
Gasoline vapor	0.05	0.1	0.01	5
Hexachlorobenzene	0.02	0.02	0.02	1
Methyl chloride	0.005	0.01	0.0002	2
Methylene chloride	0.04	0.1	0.0003	7
Perchloroethylene	0.4	3.4	0.0007	9
Polychlorinated biphenyls	0.0002	0.0003	0.000004	2
Polycyclic organic matter	0.8	1.8	0.03	7
Propylene dichloride	0.1	0.1	0.1	1
Propylene oxide	0.000007	0.000007	0.000007	1
Styrene	0.0001	0.0003	0.000005	3
Trichloroethylene	0.01	0.02	0.001	9
Vinyl chloride	0.001	0.002	0.0008	3

Caveat: Estimates of cancer incidence in these screening studies are not absolute predictions of cancer occurrence and are intended to be used in a relative sense only. See Section 2.5 for a discussion of the many assumptions and uncertainties associated with these estimates.

Table 1-4. Average Cancer Incidence by Source Category Across Studies

(excess annual cancer cases per million population within study area)

Source Category	Average Cancer Incidence	Maximum Cancer Incidence	Minimum Cancer Incidence	Number of Studies Reported
Aircraft Engines	0.3	0.3	0.3	1
Asbestos/Demolition	0.001	0.001	0.001	1
Background Carbon Tetrachloride Conc.	0.2	0.2	0.2	3
Barge Loading	0.00003	0.00003	0.00003	1
Chemical Manufacturing	2.2	11	0.00002	5
Chemical Users and Producers	1.0	1.9	0.002	2
Chrome Platers	0.5	0.5	0.3	4
Coal and Oil Combustion/Heating	0.1	0.2	0.01	5
Commercial Incinerators	0.08	0.08	0.08	1
Commercial Sterilization/Hospitals	0.04	0.1	0.007	3
Cooling Towers	0.2	0.5	0.06	3
Delaware River	0.01	0.01	0.01	1
Dry Cleaning	0.01	0.02	0.008	4
Gasoline Marketing	0.03	0.07	0.006	7
Heating/Combustion	0.06	0.2	0.008	7
Heating/Woodstoves	0.2	0.4	0.0007	7
Industrial Solvent Coating	0.04	0.04	0.04	1
Iron and Steel	0.4	1.0	0.04	4
Manufacturing Operations	0.02	0.02	0.02	1
Motor Vehicles	1.1	3.7	0.003	9
Motor Vehicles/Diesel	0.08	0.08	0.08	1
Motor Vehicles/Gasoline	0.7	0.7	0.7	1
Municipal Waste Combustors	0.0005	0.0005	0.0005	1
Municipal Waste Landfill	0.0007	0.0007	0.0007	1
Nonferrous Smelters	0.01	0.01	0.01	1
Nonroad Engines	0.3	0.3	0.3	1
Other	0.2	1.1	0.004	6
Other Miscellaneous Area Sources	0.02	0.05	0.0002	4
Other Organic Evaporation	0.01	0.02	0.005	2
Paint and Other Stripping	0.002	0.002	0.002	1
Pesticide Usage	0.01	0.01	0.01	1
Petroleum Refining	0.04	0.05	0.02	2
Point Sources	0.3	1.0	0.03	4
POTW's	0.03	0.05	0.01	2
Refractories	0.03	0.03	0.03	1
Secondary Formaldehyde Formation	0.5	0.6	0.4	4
Sewer Volatilization	0.01	0.01	0.01	1
Solvent Use/Degreasing	0.04	0.1	0.007	6
Specialty Steel	0.001	0.002	0.00006	2
Surface Coating	0.001	0.001	0.001	1
TSDF's	0.0007	0.0007	0.0007	1
Unspecified Stationary Sources	0.2	1.0	0.0002	6
Waste Oil Combustion/Burning	0.005	0.005	0.005	1

Caveat: Estimates of cancer incidence in these screening studies are not absolute predictions of cancer occurrence and are intended to be used in a relative sense only. See Section 2.5 for a discussion of the many assumptions and uncertainties associated with these estimates.

Table 1-5. Pollutants Identified for Potential Noncancer Health Effects

Pollutant	EPA Non-cancer Screening Study (13)*			Texas Study (16)		IEMP Baltimore II Study (7)
	Broad Screening Study	Urban County Study - Long-term	Urban County Study - Short-term	Dallas-Ft. Worth	Harris County	
1,1,1-Trichloroethane			X			
1,2-Dichloroethane					X	
2-Furfural **		X	X			
a-Pinene **			X			
Acetaldehyde	X		X			
Acrolein	X		X			
Acrylonitrile			X		X	
Allyl chloride					X	
Arsenic	X	X				
Asbestos (friable)				X		
Benzene	X	X	X	X	X	X
Beryllium	X					
Butyl cellosolve **			X			
Cadmium		X	X			
Carbon disulfide	X					
Carbon sulfide **			X			
Carbon tetrachloride	X					
Cellosolve **			X			
Chlorine		X	X			
Chlorobenzene			X			
Chloroform	X		X			
Chloroprene			X			
Chromium VI				X		
Copper **		X				
Cyclohexanone **			X			
Cyclopentane **			X			
Dichlorotetrafluoroethane **			X			
Dimethyl formamide			X			
Ethyl acetate **			X			
Ethyl benzene			X			
Ethylene oxide	X					
Formaldehyde	X		X		X	
Heptane **			X			
Hexamethylenediamine **			X			
Hexane			X			
Hexylene glycol **			X			
Hydrogen sulfide **	X					
Lead			X			
Manganese		X				
Mercury		X				
Methanol			X			
Methyl cellosolve **			X			
Methyl ethyl ketone	X		X			
Methyl isocyanate	X					
Methyl methacrylate	X		X			
Nitrobenzene	X					
o-Dichlorobenzene **			X			

Table 1-5. Pollutants Identified for Potential Noncancer Health Effects (cont'd)

Pollutant	EPA Non-cancer Screening Study (13)*			Texas Study (16)		IEMP Baltimore II Study (7)
	Broad Screening Study	Urban County Study - Long-term	Urban County Study - Short-term	Dallas-Ft. Worth	Harris County	
o-Xylene			X			
Perchloroethylene	X					
Phenol	X		X			
Phthalic anhydride	X		X			
Styrene	X		X			
Sulfur **			X			
Tetramethyl lead	X					
Toluene			X			
Toluene diisocyanate	X					
Vinyl chloride	X		X			
Xylene			X			

X = pollutant identified for noncancer health risks
* =source of information by reference number
** = not listed as a HAP under Section 112

Chapter 2
METHODOLOGY

2.1 Background

The purpose of this report is to compile and report the results of available exposure and risk screening studies dealing with air toxic emissions. Numerous such studies have been carried out over the past decade, and formed the basis for concern that led to an urban area source regulatory program in Section 112 of the Clean Air Act Amendments of 1990.[2] Such studies are generally considered to be broad screening studies, with many aggressive, often very conservative, assumptions necessarily having to be made to develop a comprehensive overview of the nature and magnitude of the air toxics problem in the United States. Assumptions and limitations of these studies are presented in Section 2.5. Generally, these screening studies represent exposure and cancer risk assessments based on dispersion modeling of emissions inventory data. Some of the studies summarized also factor in assessments based on ambient monitoring data. Only a few screening studies consider noncancer endpoints.

2.2 Compilation of Available Exposure and Risk Screening Studies

The following screening studies were compiled for this analysis:

- EPA five city controllability study[3*]
- EPA Integrated Environmental Management Project (IEMP) studies in KanawhaValley, WV[4*], Philadelphia, PA[5*], Santa Clara, CA[6*], and Baltimore, MD[7]
- South Coast, CA air toxics study[8*]
- Southeast Chicago, IL[9*] and Southwest Chicago, IL[10] air toxics studies
- Houston, TX air toxics risk assessment[11]
- Detroit, MI Transboundary air toxics study[12]
- EPA noncancer air toxics screening study[13-15]
- Texas air toxics assessment[16]
- Twin City cancer risk study[17]

All of these studies are cancer screening studies with the exception of the EPA noncancer study, the Texas air toxics assessment and the Baltimore IEMP, the latter including both a noncancer and cancer assessment component. The studies identified above with asterisks (*) were conducted before 1990 and summarized in EPA's 1990 EPA report entitled Cancer Risk From Outdoor Exposure to Air Toxics[1]. This analysis utilized the results of these studies as summarized in the Cancer Risk... report, and did not revisit the original studies. This was done because the Cancer Risk... authors revisited the original studies and in some cases updated the original results to reflect newer health benchmarks.

The studies identified above without asterisks were not included in the Cancer Risk... report, mainly because they were completed subsequent to 1990 or were unavailable for inclusion in the Cancer Risk... report. These additional screening study results were reported here without any attempt to update any of the methods or data utilized in them. This is very difficult to do and available resources precluded any such update.

2.3 Methodology

Each of the studies was reviewed and the cancer and noncancer incidence and health benchmark exceedances were summarized. In most of the studies, the summary data needed were directly excerpted for relative ranking purposes in this report. Where population-normalized cancer incidence data were not presented, the aggregate, areawide cancer incidence values were divided by the study area population to express cancer incidence per million population, for inter-city comparison purposes. Where cancer incidence data were not presented on an annual basis, the lifetime incidence figures were divided by 70 to adjust accordingly.

Most of the noncancer studies presented a listing of the extent or occurrence of monitored and/or modeled ambient concentrations of HAPs exceeding some specific health benchmarks. These specific health benchmarks varied by study, and included lowest-observed-adverse-effect-levels (LOAEL), health-effect-levels (HEL) determined by dividing the LOAEL by an uncertainty factor, reference concentrations (RfC), or threshold levels set by the investigators. The exposures could be acute or chronic. Given the complex and nonuniform presentations in the noncancer risk studies, it is inappropriate to compare the pollutants and their noncancer effects on a common basis. Therefore, this report only lists those pollutants in each of the studies that are identified as potentially causing a noncancer concern, but does not rank those pollutants in any prioritized order.

Salient excerpts of the results from each of these screening studies are provided in the following chapter, along with a brief summary of the purpose, methodology and sponsoring agency. Also presented along with these excerpts are the specific assumptions and limitations known to be associated with each screening study.

2.4 Additional study results

The results of this analysis are summarized in Tables 1-1 through 1-5 in Chapter 1. Additional, study-specific results are presented in Table 2-1. This table summarizes the specific cancer incidence associated with each source category-HAP combination, in descending order of importance, by study.

2.5 Screening study assumptions and limitations

All screening studies to date have made many assumptions regarding emissions/exposures/risks in order to be broadly comprehensive in the face of uncertain, changing assessment methodologies and weak, gap-laden supporting data. In fact, most of the studies have made similar assumptions, used similar assessment methodologies, and accounted for data gaps in similar ways. Sometimes these assumptions have involved default options in instances where specific data were altogether missing.

Typical assumptions and limitations commonly associated with these screening studies are recited below. These assumptions and limitations are generally excerpted verbatim directly from References 1 and 3, and are considered fairly representative of all studies summarized in this report, and of such broad screening studies, in general.

- "Personal exposure to air toxics was estimated using annual-average concentration estimates and it was assumed that exposures occu ion, only outdoor exposures were modeled. Thus, this m vements throughout the urban area, travel outside the urban are al or diurnal variations in emissions."

Important

- "The study relied solely on quantitative ated with inhalation of ambient air over long periods. Acute included, and cancer cases associated with exposure routes c air were not quantified."

- "Only 25 compounds were explicitly included in this study, although monitoring studies have shown that urban atmospheres typically obtain additional carcinogenic pollutants. The compounds selected for study were chosen because they were estimated to be the most important contributors to excess cancer incidence."

- "This study focused on routine, continuous emissions. Accidental releases were not modeled."

- "Unit risk factors employed in this study represent the chance of contracting cancer from a lifetime (70 years) exposure to a given concentration of that pollutant. It was assumed that the resulting lifetime incidence levels could be divided by 70 to represent annual incidence levels. The carcinogenic potency estimates used in this study were developed by EPA's Carcinogen Assessment Group, and generally represent conservative (upper bound) dose/response relationships."

- "Unit risk factors used in this study have been generated, in most instances, using EPA approaches or models. Most of the resulting unit risk factors are generally regarded either as plausible, upper-bound estimates or as maximum likelihood estimates. The linearized multistage procedure used to derive these factors leads to a plausible upper limit to the risk that is consistent with some proposed mechanisms of carcinogenesis. Such estimates, however, do not necessarily give a realistic prediction of the risk. The true value of the risk is unknown, and may be as low as zero."

- "Cancer incidence estimates are presented for "existing" conditions (1980). These incidence estimates are based on the assumption that emission levels for each scenario remain constant for a 70-year period. In reality, emissions will vary from year to year."

- "Sources included in the exposure modeling data set for each study area were limited to those in the counties under study. Therefore, while contributions from these sources to areas outside the county boundaries were considered, contributions of sources outside the county boundaries to air toxic concentrations within the study areas were not."

- "Except for secondary formaldehyde exposure formation, atmospheric transformation of toxic compounds and precursors had been ignored. Both secondary formation and scavenging may occur for the compounds included in this study. Thus, it is difficult to quantify how neglecting transformation might affect the final results."

- "Incidence from formaldehyde exposure was estimated using ambient monitoring data and assuming that everyone with an urban area is exposed to the same concentration. This is a relatively crude technique, but because so much of formaldehyde is formed secondarily, this procedure was judged to be preferable to modeling direct formaldehyde concentrations and ignoring secondary formation."

- "It has been suggested that global background concentrations of some toxic compounds, notably carbon tetrachloride, may be contributing significantly to observed ambient readings. No attempt has been made in the dispersion modeling performed for this study to account for background concentrations."

- "The handling of some point sources as area sources for modeling purposes may introduce some upward bias in the resulting exposure/risk estimates since HEM (EPA's Human Exposure Model) distributes area source emissions by populations and since area sources are emitted closer to ground level."

- "Any study such as this represents a "snapshot in time" on one's collective understanding of the urban air toxics problem. In fact, the emission estimates and dose-response relationships used in this study are subject to frequent revision as newer data become available. Hence, care should be taken when interpreting any results from this study or comparing these results to those from other studies where different data have been used."

- "All risks are assumed to be additive. This assumption can lead to substantial errors in risk estimated if synergistic or antagonistic interactions occur. Although dose additivity has been shown to predict the acute toxicities of many mixtures of similar compounds, some marked exceptions have been noted. Consequently, additivity assumptions may substantially overestimate risk in some cases and underestimate it in others. The available data on mixtures are insufficient for estimating the magnitude of these errors. Based on current compounds that induce similar types of effects at the same sites of action."

- "In the case of chromium, only the hexavalent form has been proven to be carcinogenic. The percentage of total chromium that is hexavalent is known to vary considerably depending on the source. For example, hexavalent chromium is less than 1 percent of total chromium emissions from coal and oil burning combustion, while it is nearly 100 percent of total chromium emissions from cooling towers and electroplating. Nevertheless, considerable uncertainty remains as to the exposure to hexavalent chromium versus total chromium emissions."

- "In the case of PIC [products of incomplete combustion], there are several sources of uncertainty. There are a number of methodologies available to estimate risk from PIC. Some of these methodologies use BaP as a surrogate for both PIC emissions and unit risk value. Others use PIC-specific emission factors and unit risk factors or comparative potency factors. The estimates of cancer incidence are seen to vary by a factor of 200 depending on which

methodology is used. While no one methodology has been shown to be a better methodology for estimating risk from PIC, this study uses the methodology that relies on PIC-specific emission factors and unit risk factor or comparative potency factors."

- "While the comparative potency approach used to estimate POM risks for several important sources is judged to be an improvement, conceptually, over previous techniques which used B(a)P as a surrogate for POM, available comparative potency factors are, in fact, based on few measurements, especially for the important motor vehicle categories, and the uncertainty in these values should be recognized."

- Dioxins/furans are only handled in a few studies[9,10,12], and the details for emissions/exposure/risk assessment are not described in these reports. The unit risk factors were based on a variation of EPA's "Interim Procedures for Estimating Risk Associated with Exposures to Mixtures of Chlorinated Dibenzo-p-dioxins and Dibenzofurans (CDDs and CDFs).[18]

Another limitation not explicitly mentioned in these studies, with respect to using the study results in the urban area source program, is that **none of the cancer screening studies expressly distinguishes between major and area source categories per the Section 112(a) definition, which is based on an emission threshold of 10 tons/year (TPY) of any single HAP or 25 TPY of any combination of HAPs. Hence, area sources of HAPs could not clearly be identified or ranked by cancer incidence based on these study results, pursuant to this 10/25 TPY threshold.**

All of the studies summarized in this report were completed before publication of the National Academy of Science's (NAS), 1994 report "Science and Judgement in Risk Assessment. [19] The NAS report was carried out pursuant to the 1990 Clean Air Act Amendments to address important evolving issues regarding risk assessment of hazardous air pollutants. While this report encourages certain improvements in risk assessment methods, it does not conclude that assessments cannot be useful even if many default assumptions are made. Instead, the report recommends that "EPA should continue to regard the use of default options as a reasonable way to deal with uncertainty about underlying mechanisms in selecting methods and models for use in risk assessment." However, the NAS also recommends that EPA should explicitly identify and state the scientific and policy basis for each use of a default option in risk assessments and, of course, improve its methods where resources and data make this possible. Hence, it is important to be aware of the many limitations and assumptions in the screening studies reported herein before considering the results in National Strategy development.

Table 2-1. Cancer Incidence by Pollutant and Source Category for Each Study

Pollutant	Source category	Study (Reference)	Cancer Incidence (cases/million people)
Polycyclic organic matter	Motor Vehicles	5-City (Reference 1)	1
1,3-Butadiene	Motor Vehicles	5-City	0.8
Formaldehyde	Secondary Formaldehyde Formation	5-City	0.6
Chromium (VI)	Chrome Platers	5-City	0.5
Chromium (VI)	Cooling Towers	5-City	0.5
Benzene	Motor Vehicles	5-City	0.4
Polycyclic organic matter	Heating/Woodstoves	5-City	0.3
Formaldehyde	Motor Vehicles	5-City	0.3
Ethylene oxide	Commercial Sterilization/Hospitals	5-City	0.1
Polycyclic organic matter	Other	5-City	0.06
Benzene	Heating/Woodstoves	5-City	0.06
1,2-Dichloroethane	Unspecified Stationary Sources	5-City	0.05
Gasoline vapor	Gasoline Marketing	5-City	0.05
Arsenic, inorganic	Other	5-City	0.05
Chromium (VI)	Refractories	5-City	0.03
Carbon tetrachloride	Unspecified Stationary Sources	5-City	0.03
Formaldehyde	Heating/Combustion	5-City	0.03
Arsenic, inorganic	Coal and Oil Combustion/Heating	5-City	0.02
1,3-Butadiene	Chemical Manufacturing	5-City	0.02
Polycyclic organic matter	Iron and Steel	5-City	0.02
Benzene	Iron and Steel	5-City	0.02
Methylene chloride	Solvent Use	5-City	0.02
Benzene	Gasoline Marketing	5-City	0.02
Benzene	Other Organic Evaporation	5-City	0.02
Formaldehyde	Heating/Woodstoves	5-City	0.01
Benzene	Chemical Manufacturing	5-City	0.01
Perchloroethylene	Dry Cleaning	5-City	0.01
Formaldehyde	Petroleum Refining	5-City	0.01
Perchloroethylene	Solvent Use/Degreasing	5-City	0.01
Chloroform	Unspecified Stationary Sources	5-City	0.01
Trichloroethylene	Solvent Use/Degreasing	5-City	0.01
Formaldehyde	Nonferrous Smelters	5-City	0.01
Ethylene oxide	Unspecified Stationary Sources	5-City	0.01
Cadmium	Heating/Combustion	5-City	0.009
Formaldehyde	Unspecified Stationary Sources	5-City	0.009
Benzene	Petroleum Refining	5-City	0.005
Formaldehyde	Chemical Manufacturing	5-City	0.003
Polycyclic organic matter	Coal and Oil Combustion/Heating	5-City	0.002
Ethylene oxide	Chemical Manufacturing	5-City	0.002
Perchloroethylene	Chemical Manufacturing	5-City	0.001
Chloroform	Chemical Users and Producers	5-City	0.001
1,2-Dichloroethane	Gasoline Marketing	5-City	0.0008
Arsenic, inorganic	Heating/Woodstoves	5-City	0.0008
Vinyl chloride	Unspecified Stationary Sources	5-City	0.0008
Carbon tetrachloride	Chemical Users and Producers	5-City	0.0006
Arsenic, inorganic	Nonferrous Smelters	5-City	0.0006
1,2-Dichloroethane	Chemical Manufacturing	5-City	0.0005
Benzene	Heating/Combustion	5-City	0.0004
Chromium (VI)	Heating/Combustion	5-City	0.0003
Cadmium	Unspecified Stationary Sources	5-City	0.0002
Trichloroethylene	Unspecified Stationary Sources	5-City	0.0002
Chromium (VI)	Specialty Steel	5-City	0.00006
Arsenic, inorganic	Solvent Use	5-City	0.00006

CAVEAT: Estimates of cancer incidence in these screening studies are not absolute predictions of cancer occurrence and are intended to be used in a relative sense only. See Section 2.5, for a discussion of the many assumptions and uncertainties associated with these estimates.
NOTE: Studies whose results were excerpted from EPA's Cancer Risk...., report (Ref 1), rather than the primary study reference itself, cite "Reference 1" in the above table. Rationale for this are explained in Section 2.2.

Table 2-1. Cancer Incidence by Pollutant and Source Category for Each Study
(continued)

Pollutant	Source category	Study (Reference)	Cancer Incidence (cases/million people)
Vinyl chloride	Chemical Manufacturing	5-City	0.00002
Formaldehyde	Solvent Use	5-City	0.00002
Trichloroethylene	Chemical Manufacturing	5-City	0.000001
1,3-Butadiene	Other	Harris County, TX (Ref. 11)	0.8
Formaldehyde	Other	Harris County, TX	0.3
1,3-Butadiene	Point Sources	Harris County, TX	0.07
Formaldehyde	Point Sources	Harris County, TX	0.06
Benzene	Point Sources	Harris County, TX	0.02
Benzene	Other	Harris County, TX	0.01
Methyl chloride	Other	Harris County, TX	0.01
Formaldehyde	Motor Vehicles	Harris County, TX	0.002
Methyl chloride	Point Sources	Harris County, TX	0.002
Benzene	Motor Vehicles	Harris County, TX	0.001
Benzene	Other Miscellaneous Area Sources	Harris County, TX	0.0001
Formaldehyde	Other Miscellaneous Area Sources	Harris County, TX	0.00006
Polycyclic organic matter	Point Sources	IEMP-Baltimore II (Ref. 7)	0.6
Polycyclic organic matter	Motor Vehicles/Gasoline	IEMP-Baltimore II	0.5
Chromium (VI)	Point Sources	IEMP-Baltimore II	0.3
Polycyclic organic matter	Coal and Oil Combustion/Heating	IEMP-Baltimore II	0.09
Polycyclic organic matter	Motor Vehicles/Diesel	IEMP-Baltimore II	0.08
Methylene chloride	Solvent Use	IEMP-Baltimore II	0.08
Benzene	Motor Vehicles/Gasoline	IEMP-Baltimore II	0.07
Arsenic, inorganic	Coal and Oil Combustion/Heating	IEMP-Baltimore II	0.06
Benzene	Point Sources	IEMP-Baltimore II	0.06
Polycyclic organic matter	Heating/Combustion	IEMP-Baltimore II	0.06
Formaldehyde	Motor Vehicles/Gasoline	IEMP-Baltimore II	0.06
Methylene chloride	Other	IEMP-Baltimore II	0.05
Cadmium	Coal and Oil Combustion/Heating	IEMP-Baltimore II	0.03
Arsenic, inorganic	Heating/Combustion	IEMP-Baltimore II	0.03
Arsenic, inorganic	Point Sources	IEMP-Baltimore II	0.03
Perchloroethylene	Dry Cleaning	IEMP-Baltimore II	0.02
Polycyclic organic matter	Heating/Woodstoves	IEMP-Baltimore II	0.02
Methylene chloride	Solvent Use/Degreasing	IEMP-Baltimore II	0.02
Trichloroethylene	Solvent Use/Degreasing	IEMP-Baltimore II	0.02
Benzene	Gasoline Marketing	IEMP-Baltimore II	0.006
Formaldehyde	Motor Vehicles/Diesel	IEMP-Baltimore II	0.006
Cadmium	Point Sources	IEMP-Baltimore II	0.006
Perchloroethylene	Solvent Use/Degreasing	IEMP-Baltimore II	0.006
Ethylene oxide	Chemical Manufacturing	IEMP-Kanawha Valley (Ref. 1)	8
1,3-Butadiene	Motor Vehicles	IEMP-Kanawha Valley	3
Acrylonitrile	Chemical Manufacturing	IEMP-Kanawha Valley	2
Chloroform	Chemical Users and Producers	IEMP-Kanawha Valley	2
1,3-Butadiene	Chemical Manufacturing	IEMP-Kanawha Valley	1
Benzene	Motor Vehicles	IEMP-Kanawha Valley	0.4
Arsenic, inorganic	Coal and Oil Combustion/Heating	IEMP-Kanawha Valley	0.2
Methylene chloride	Chemical Users and Producers	IEMP-Kanawha Valley	0.03
Perchloroethylene	Solvent Use/Degreasing	IEMP-Kanawha Valley	0.03
Cadmium	Heating/Combustion	IEMP-Kanawha Valley	0.02
Polycyclic organic matter	Heating/Woodstoves	IEMP-Kanawha Valley	0.02
Polycyclic organic matter	Motor Vehicles	IEMP-Kanawha Valley	0.01
Methylene chloride	Solvent Use	IEMP-Kanawha Valley	0.01
1,2-Dibromoethane	Motor Vehicles	IEMP-Kanawha Valley	0.01
Trichloroethylene	Solvent Use/Degreasing	IEMP-Kanawha Valley	0.01

CAVEAT: Estimates of cancer incidence in these screening studies are not absolute predictions of cancer occurrence and are intended to be used in a relative sense only. See Section 2.5, for a discussion of the many assumptions and uncertainties associated with these estimates.
NOTE: Studies whose results were excerpted from EPA's Cancer Risk...., report (Ref 1), rather than the primary study reference itself, cite "Reference 1" in the above table. Rationale for this are explained in Section 2.2.

Table 2-1. Cancer Incidence by Pollutant and Source Category for Each Study
(continued)

Pollutant	Source category	Study (Reference)	Cancer Incidence (cases/million people)
Dichloroethene	Chemical Manufacturing	IEMP-Kanawha Valley	0.01
Benzene	Gasoline Marketing	IEMP-Kanawha Valley	0.009
Cadmium	Motor Vehicles	IEMP-Kanawha Valley	0.005
Arsenic, inorganic	Waste Oil Combustion/Burning	IEMP-Kanawha Valley	0.004
1,2-Dichloroethane	Gasoline Marketing	IEMP-Kanawha Valley	0.004
Trichloroethylene	Chemical Manufacturing	IEMP-Kanawha Valley	0.003
1,2-Dibromoethane	Gasoline Marketing	IEMP-Kanawha Valley	0.003
Cadmium	Waste Oil Combustion/Burning	IEMP-Kanawha Valley	0.0009
1,2-Dichloroethane	Unspecified Stationary Sources	IEMP-Kanawha Valley	0.0002
1,2-Dichloroethane	POTW's	IEMP-Philadelphia (Ref. 1)	0.05
Gasoline vapor	Petroleum Refining	IEMP-Philadelphia	0.03
Gasoline vapor	Gasoline Marketing	IEMP-Philadelphia	0.03
1,2-Dichloroethane	Delaware River	IEMP-Philadelphia	0.01
Perchloroethylene	Dry Cleaning	IEMP-Philadelphia	0.01
1,2-Dichloroethane	Sewer Volatilization	IEMP-Philadelphia	0.01
Trichloroethylene	Solvent Use/Degreasing	IEMP-Philadelphia	0.01
1,2-Dichloroethane	Petroleum Refining	IEMP-Philadelphia	0.007
Benzene	Petroleum Refining	IEMP-Philadelphia	0.006
Perchloroethylene	Solvent Use/Degreasing	IEMP-Philadelphia	0.002
Benzene	Gasoline Marketing	IEMP-Philadelphia	0.002
1,2-Dichloroethane	Gasoline Marketing	IEMP-Philadelphia	0.0005
Perchloroethylene	POTW's	IEMP-Philadelphia	0.0005
Benzene	POTW's	IEMP-Philadelphia	0.0002
Trichloroethylene	Unspecified Stationary Sources	IEMP-Philadelphia	0.0002
1,2-Dichloroethane	Chemical Manufacturing	IEMP-Philadelphia	0.00002
Benzene	Motor Vehicles	IEMP-Santa Clara (Ref. 1)	0.1
Benzene	Industrial Solvent Coating	IEMP-Santa Clara	0.04
Benzene	Heating/Combustion	IEMP-Santa Clara	0.02
Benzene	Pesticide Usage	IEMP-Santa Clara	0.01
Benzene	Unspecified Stationary Sources	IEMP-Santa Clara	0.007
Benzene	Gasoline Marketing	IEMP-Santa Clara	0.007
Benzene	Other Organic Evaporation	IEMP-Santa Clara	0.005
Benzene	Chemical Manufacturing	IEMP-Santa Clara	0.002
Benzene	Municipal Waste Combustors	IEMP-Santa Clara	0.0005
Chromium (VI)	Unspecified Stationary Sources	South Coast (Ref. 1)	0.6
Benzene	Motor Vehicles	South Coast	0.4
Benzene	Unspecified Stationary Sources	South Coast	0.4
Chromium (VI)	Motor Vehicles	South Coast	0.1
Cadmium	Motor Vehicles	South Coast	0.04
1,2-Dibromoethane	Motor Vehicles	South Coast	0.002
Coke oven emissions	Iron and Steel	Southeast Chicago (Ref. 1)	0.9
Chromium (VI)	Chrome Platers	Southeast Chicago	0.5
Formaldehyde	Secondary Formaldehyde Formation	Southeast Chicago	0.4
Polycyclic organic matter	Heating/Woodstoves	Southeast Chicago	0.3
Carbon tetrachloride	Background Concentrations	Southeast Chicago	0.2
1,3-Butadiene	Motor Vehicles	Southeast Chicago	0.3
Polycyclic organic matter	Motor Vehicles	Southeast Chicago	0.1
Gasoline vapor	Motor Vehicles	Southeast Chicago	0.1
Benzene	Iron and Steel	Southeast Chicago	0.08
Benzene	Motor Vehicles	Southeast Chicago	0.07
Chromium (VI)	Cooling Towers	Southeast Chicago	0.06
Arsenic, inorganic	Iron and Steel	Southeast Chicago	0.05
Formaldehyde	Motor Vehicles	Southeast Chicago	0.05

CAVEAT: Estimates of cancer incidence in these screening studies are not absolute predictions of cancer occurrence and are intended to be used in a relative sense only. See Section 2.5, for a discussion of the many assumptions and uncertainties associated with these estimates.
NOTE: Studies whose results were excerpted from EPA's Cancer Risk..., report (Ref 1), rather than the primary study reference itself, cite "Reference 1" in the above table. Rationale for this are explained in Section 2.2.

Table 2-1. Cancer Incidence by Pollutant and Source Category for Each Study
(continued)

Pollutant	Source category	Study (Reference)	Cancer Incidence (cases/million people)
Gasoline vapor	Gasoline Marketing	Southeast Chicago	0.03
Cadmium	Iron and Steel	Southeast Chicago	0.03
Ethylene oxide	Commercial Sterilization/Hospitals	Southeast Chicago	0.01
Formaldehyde	Heating/Combustion	Southeast Chicago	0.008
Formaldehyde	Unspecified Stationary Sources	Southeast Chicago	0.008
Trichloroethylene	Solvent Use/Degreasing	Southeast Chicago	0.007
Ethylene oxide	Unspecified Stationary Sources	Southeast Chicago	0.007
Arsenic, inorganic	Other	Southeast Chicago	0.004
Benzene	Other Miscellaneous Area Sources	Southeast Chicago	0.004
Chromium (VI)	Specialty Steel	Southeast Chicago	0.002
Benzene	Unspecified Stationary Sources	Southeast Chicago	0.002
1,2-Dibromoethane	Motor Vehicles	Southeast Chicago	0.002
1,2-Dichloroethane	Unspecified Stationary Sources	Southeast Chicago	0.002
Perchloroethylene	Chemical Manufacturing	Southeast Chicago	0.001
Cadmium	Motor Vehicles	Southeast Chicago	0.0004
Trichloroethylene	TSDF's	Southeast Chicago	0.0004
2,3,7,8-TCDDioxin	TSDF's	Southeast Chicago	0.0004
Cadmium	Unspecified Stationary Sources	Southeast Chicago	0.0004
Chromium (VI)	Chrome Platers	Southwest Chicago (Ref. 10)	0.5
Formaldehyde	Background Concentrations	Southwest Chicago	0.4
1,3-Butadiene	Motor Vehicles	Southwest Chicago	0.3
Polycyclic organic matter	Motor Vehicles	Southwest Chicago	0.3
1,3-Butadiene	Aircraft Engines	Southwest Chicago	0.2
Coke oven emissions	Steel Mills/Iron and Steel	Southwest Chicago	0.2
1,3-Butadiene	Nonroad Engines	Southwest Chicago	0.2
Carbon tetrachloride	Background Concentrations	Southwest Chicago	0.2
Polycyclic organic matter	Nonroad Engines	Southwest Chicago	0.1
Formaldehyde	Aircraft Engines	Southwest Chicago	0.07
Chromium (VI)	Cooling Towers	Southwest Chicago	0.07
Benzene	Motor Vehicles	Southwest Chicago	0.06
Polycyclic organic matter	Aircraft Engines	Southwest Chicago	0.06
Polycyclic organic matter	Other	Southwest Chicago	0.05
Benzene	Steel Mills/Iron and Steel	Southwest Chicago	0.04
Gasoline vapor	Gasoline Marketing	Southwest Chicago	0.04
Formaldehyde	Motor Vehicles	Southwest Chicago	0.03
Ethylene oxide	Point Sources	Southwest Chicago	0.02
Arsenic, inorganic	Steel Mills/Iron and Steel	Southwest Chicago	0.02
Arsenic, inorganic	Point Sources	Southwest Chicago	0.02
Hexachlorobenzene	POTW's	Southwest Chicago	0.01
Benzene	Nonroad Engines	Southwest Chicago	0.01
Chromium (VI)	Coal and Oil Combustion/Heating	Southwest Chicago	0.01
1,3-Butadiene	Other	Southwest Chicago	0.01
Trichloroethylene	Solvent Use/Degreasing	Southwest Chicago	0.01
Polycyclic organic matter	Heating/Combustion	Southwest Chicago	0.009
Chloroform	Other Miscellaneous Area Sources	Southwest Chicago	0.009
Perchloroethylene	Dry Cleaning	Southwest Chicago	0.008
Formaldehyde	Other Miscellaneous Area Sources	Southwest Chicago	0.008
Formaldehyde	Heating/Combustion	Southwest Chicago	0.008
Cadmium	Steel Mills/Iron and Steel	Southwest Chicago	0.007
Formaldehyde	Nonroad Engines	Southwest Chicago	0.007
Ethylene oxide	Commercial Sterilization/Hospitals	Southwest Chicago	0.007
Benzene	Aircraft Engines	Southwest Chicago	0.006
Carbon tetrachloride	Point Sources	Southwest Chicago	0.006

CAVEAT: Estimates of cancer incidence in these screening studies are not absolute predictions of cancer occurrence and are intended to be used in a relative sense only. See Section 2.5 for a discussion of the many assumptions and uncertainties associated with these estimates.
NOTE: Studies whose results were excerpted from EPA's Cancer Risk... report (Ref. 1), rather than the primary study reference itself, cite "Reference 1" in the above table. Rationale for this are explained in Section 2.2.

Table 2-1. Cancer Incidence by Pollutant and Source Category for Each Study
(continued)

Pollutant	Source category	Study (Reference)	Cancer Incidence (cases/million people)
Formaldehyde	Point Sources	Southwest Chicago	0.006
Hexachlorobenzene	TSDF's	Southwest Chicago	0.005
Chromium (VI)	Heating/Combustion	Southwest Chicago	0.004
Asbestos (friable)	Motor Vehicles	Southwest Chicago	0.004
Methylene chloride	Other Miscellaneous Area Sources	Southwest Chicago	0.003
2,3,7,8-TCDDioxin	Point Sources	Southwest Chicago	0.003
Methylene chloride	Paint and Other Stripping	Southwest Chicago	0.002
Cadmium	Point Sources	Southwest Chicago	0.002
Perchloroethylene	Solvent Use/Degreasing	Southwest Chicago	0.002
Methylene chloride	Solvent Use/Degreasing	Southwest Chicago	0.002
Trichloroethylene	Point Sources	Southwest Chicago	0.001
Asbestos (friable)	Asbestos/Demolition	Southwest Chicago	0.001
Benzene	Point Sources	Southwest Chicago	0.001
1,2-Dichloroethane	Point Sources	Southwest Chicago	0.001
Formaldehyde	Coal and Oil Combustion/Heating	Southwest Chicago	0.001
Perchloroethylene	Point Sources	Southwest Chicago	0.001
1,2-Dibromoethane	Point Sources	Southwest Chicago	0.001
Gasoline vapor	Point Sources	Southwest Chicago	0.0009
Methylene chloride	Surface Coating	Southwest Chicago	0.0008
Vinyl chloride	TSDF's	Southwest Chicago	0.0007
Polycyclic organic matter	Heating/Woodstoves	Southwest Chicago	0.0007
Benzene	Gasoline Marketing	Southwest Chicago	0.0007
Acrylonitrile	Point Sources	Southwest Chicago	0.0006
Vinyl chloride	Point Sources	Southwest Chicago	0.0005
Trichloroethylene	TSDF's	Southwest Chicago	0.0005
Hexachlorobenzene	Point Sources	Southwest Chicago	0.0005
Chromium (VI)	Other	Southwest Chicago	0.0005
Chromium (VI)	Steel Mills/Iron and Steel	Southwest Chicago	0.0005
Dichloroethene	TSDF's	Southwest Chicago	0.0004
Vinyl chloride	Municipal Waste Landfill	Southwest Chicago	0.0004
1,3-Butadiene	TSDF's	Southwest Chicago	0.0003
Methyl chloride	Surface Coating	Southwest Chicago	0.0002
Methylene chloride	TSDF's	Southwest Chicago	0.0002
Dichloroethene	Municipal Waste Landfill	Southwest Chicago	0.0002
Formaldehyde	Steel Mills/Iron and Steel	Southwest Chicago	0.0001
Methylene chloride	Point Sources	Southwest Chicago	0.0001
Benzene	TSDF's	Southwest Chicago	0.0001
Chloroform	POTW's	Southwest Chicago	0.0001
Benzene	Surface Coating	Southwest Chicago	0.00009
Cadmium	Motor Vehicles	Southwest Chicago	0.00006
Styrene	Point Sources	Southwest Chicago	0.00005
Perchloroethylene	Municipal Waste Landfill	Southwest Chicago	0.00005
Methylene chloride	Municipal Waste Landfill	Southwest Chicago	0.00005
Perchloroethylene	POTW's	Southwest Chicago	0.00003
Trichloroethylene	Municipal Waste Landfill	Southwest Chicago	0.00003
Trichloroethylene	POTW's	Southwest Chicago	0.00003
Benzene	Barge Loading	Southwest Chicago	0.00003
Chloroform	TSDF's	Southwest Chicago	0.00003
Methylene chloride	POTW's	Southwest Chicago	0.00003
1,3-Butadiene	Steel Mills/Iron and Steel	Southwest Chicago	0.00002
1,2-Dichloroethane	POTW's	Southwest Chicago	0.00002
2,3,7,8-TCDDioxin	TSDF's	Southwest Chicago	0.00001
Acrylamide	Point Sources	Southwest Chicago	0.00001

CAVEAT: Estimates of cancer incidence in these screening studies are not absolute predictions of cancer occurrence and are intended to be used in a relative sense only. See Section 2.5 for a discussion of the many assumptions and uncertainties associated with these estimates.
NOTE: Studies whose results were excerpted from EPA's Cancer Risk... report (Ref. 1), rather than the primary study reference itself, cite "Reference 1" in the above table. Rationale for this are explained in Section 2.2.

Table 2-1. Cancer Incidence by Pollutant and Source Category for Each Study
(continued)

Pollutant	Source category	Study (Reference)	Cancer Incidence (cases/million people)
Epichlorohydrin	Point Sources	Southwest Chicago	0.00001
Benzene	Municipal Waste Landfill	Southwest Chicago	0.000009
Benzene	POTW's	Southwest Chicago	0.000009
Propylene oxide	Point Sources	Southwest Chicago	0.000007
Styrene	POTW's	Southwest Chicago	0.000007
Asbestos (friable)	TSDF's	Southwest Chicago	0.000005
Dichloroethene	POTW's	Southwest Chicago	0.000005
1,2-Dichloroethane	TSDF's	Southwest Chicago	0.000004
Styrene	TSDF's	Southwest Chicago	0.000004
Perchloroethylene	TSDF's	Southwest Chicago	0.000004
Polychlorinated biphenyls	TSDF's	Southwest Chicago	0.000004
Methyl chloride	Point Sources	Southwest Chicago	0.000003
Chloroform	Point Sources	Southwest Chicago	0.000002
Arsenic, inorganic	TSDF's	Southwest Chicago	0.000002
Beryllium	Point Sources	Southwest Chicago	0.0000009
Methyl chloride	POTW's	Southwest Chicago	0.0000008
Formaldehyde	TSDF's	Southwest Chicago	0.0000005
Cadmium	TSDF's	Southwest Chicago	0.0000004
Acrylonitrile	TSDF's	Southwest Chicago	0.0000004
Polychlorinated biphenyls	Point Sources	Southwest Chicago	0.0000004
Polychlorinated biphenyls	Municipal Waste Landfill	Southwest Chicago	0.00000004
Beryllium	TSDF's	Southwest Chicago	9E-09
Methyl chloride	TSDF's	Southwest Chicago	3E-09
Chromium (VI)	TSDF's	Southwest Chicago	3E-09
Epichlorohydrin	TSDF's	Southwest Chicago	3E-09
Diesel PM	Motor Vehicles	Twin City (Ref. 17)	0.7
Gasoline PM	Motor Vehicles	Twin City	0.4
Woodstove PM	Heating/Woodstoves	Twin City	0.4
1,3-Butadiene	Motor Vehicles	Twin City	0.3
Chromium (VI)	Chrome Platers	Twin City	0.3
Polycyclic organic matter	Heating/Combustion	Twin City	0.2
Benzene	Motor Vehicles	Twin City	0.1
Polycyclic organic matter	Commercial Incinerators	Twin City	0.08
Formaldehyde	Motor Vehicles	Twin City	0.06
Formaldehyde	Heating/Woodstoves	Twin City	0.03
Chromium (VI)	Other Miscellaneous Area Sources	Twin City	0.02
Arsenic, inorganic	Heating/Combustion	Twin City	0.01
Trichloroethylene	Other Miscellaneous Area Sources	Twin City	0.01
Cadmium	Heating/Combustion	Twin City	0.009
Arsenic, inorganic	Point Sources	Twin City	0.005
Ethylene oxide	Other Miscellaneous Area Sources	Twin City	0.005
Perchloroethylene	Other Miscellaneous Area Sources	Twin City	0.005
Ethylene oxide	Point Sources	Twin City	0.004
Benzene	Point Sources	Twin City	0.004
Methylene chloride	Other Miscellaneous Area Sources	Twin City	0.004
1,2-Dibromoethane	Point Sources	Twin City	0.004
1,3-Butadiene	Point Sources	Twin City	0.004
Formaldehyde	Point Sources	Twin City	0.003
Trichloroethylene	Point Sources	Twin City	0.003
PAHCs	Commercial Incinerators	Twin City	0.002
Formaldehyde	Heating/Combustion	Twin City	0.002
Cadmium	Point Sources	Twin City	0.002
Arsenic, inorganic	Heating/Woodstoves	Twin City	0.002

CAVEAT: Estimates of cancer incidence in these screening studies are not absolute predictions of cancer occurrence and are intended to be used in a relative sense only. See Section 2.5 for a discussion of the many assumptions and uncertainties associated with these estimates.
NOTE: Studies whose results were excerpted from EPA's Cancer Risk... report (Ref. 1), rather than the primary study reference itself, cite "Reference 1" in the above table. Rationale for this are explained in Section 2.2.

Table 2-1. Cancer Incidence by Pollutant and Source Category for Each Study
(continued)

Pollutant	Source category	Study (Reference)	Cancer Incidence (cases/million people)
Benzene	Other Miscellaneous Area Sources	Twin City	0.001
1,2-Dichloroethane	Other Miscellaneous Area Sources	Twin City	0.0007
Methylene chloride	Point Sources	Twin City	0.0006
1,2-Dibromoethane	Other Miscellaneous Area Sources	Twin City	0.0006
Chromium (VI)	Point Sources	Twin City	0.0005
Perchloroethylene	Point Sources	Twin City	0.0003
Beryllium	Heating/Combustion	Twin City	0.0002
Arsenic, inorganic	Other Miscellaneous Area Sources	Twin City	0.0001
1,2-Dichloroethane	Point Sources	Twin City	0.0001
Cadmium	Heating/Woodstoves	Twin City	0.00008
Chromium (VI)	Heating/Combustion	Twin City	0.00008
Beryllium	Other Miscellaneous Area Sources	Twin City	0.00007
Acrylonitrile	Point Sources	Twin City	0.00002
PAHCs	Heating/Combustion	Twin City	0.00001
Cadmium	Other Miscellaneous Area Sources	Twin City	0.000007
Formaldehyde	Other Miscellaneous Area Sources	Twin City	0.000006
Styrene	Point Sources	Twin City	0.000005
PAHCs	Other Miscellaneous Area Sources	Twin City	0.000002
Acetaldehyde	Point Sources	Twin City	0.000001
Formaldehyde		Detroit (Ref. 12)	0.4
Coke oven emissions		Detroit	0.2
1,3-Butadiene		Detroit	0.2
Carbon tetrachloride		Detroit	0.2
Chromium (VI)		Detroit	0.05
Polycyclic organic matter		Detroit	0.04
2,3,7,8-TCDDioxin		Detroit	0.04
Arsenic, inorganic		Detroit	0.02
Beryllium		Detroit	0.02
Asbestos (friable)		Detroit	0.02
Benzene		Detroit	0.02
Gasoline vapor		Detroit	0.01
Cadmium		Detroit	0.005
1,2-Dibromoethane		Detroit	0.002
Vinyl chloride		Detroit	0.001
Trichloroethylene		Detroit	0.001
Perchloroethylene		Detroit	0.0007
Polychlorinated biphenyls		Detroit	0.0003
Styrene		Detroit	0.0003
Methylene chloride		Detroit	0.0003
Chloroform		Detroit	0.00001
Acrylonitrile		Detroit	0.000003
Epichlorohydrin		Detroit	0.000003
Ethylene oxide		Detroit	0.000003
	Secondary Formaldehyde Formation*	Detroit	0.5
	Iron and Steel*	Detroit	0.2
	Background Concentrations*	Detroit	0.2
	Motor Vehicles*	Detroit	0.1
	Other*	Detroit	0.1
	Coal and Oil Combustion/Heating*	Detroit	0.08
	Manufacturing Operations*	Detroit	0.02
	Heating/Woodstoves*	Detroit	0.001

* The Detroit study did not jointly analyze pollutant and source category effects. Therefore, what is presented are specific chemical effects for all source categories combined and specific source category effects for all chemicals combined. The sum of cancer incidences for both of these subcategories are necessarily equal and inclusion of both subcategories to obtain a total cancer incidence would lead to double counting.

CAVEAT: Estimates of cancer incidence in these screening studies are not absolute predictions of cancer occurrence and are intended to be used in a relative sense only. See Section 2.5, for a discussion of the many assumptions and uncertainties associated with these estimates.
NOTE: Studies whose results were excerpted from EPA's Cancer Risk...., report (Ref 1), rather than the primary study reference itself, cite "Reference 1" in the above table. Rationale for this are explained in Section 2.2.

Chapter 3
SUMMARIES OF NEW STUDIES

Seven studies were compiled for this report in addition to those studies that were already summarized in EPA's 1990 EPA report entitled Cancer Risk From Outdoor Exposure to Air Toxics[1]. The studies summarized in Cancer Risk... are not summarized again herein. Only the seven additional studies not included in Cancer Risk... are summarized below. For each of these seven studies, a brief discussion of background and methodology is presented, along with study results and the assumptions and limitations associated with the study. Much of the material presented here, particularly the graphics showing each study's results, is taken verbatim from these studies (and labeled as such).

3.1 Southwest Chicago Study[10]

Report Title/Date: Estimation and Evaluation of Cancer Risks Attributed to Air Pollution in Southwest Chicago, April 1993

Conducted by: U.S. EPA Region 5, Air and Radiation Division

Background and Methodology: The purpose of this study was to estimate the cancer risks associated with 30 carcinogenic air pollutants in the Southwest Chicago area. The study was conducted by ViGYAN Inc. in Falls Church, Virginia for U.S. EPA Region 5, Air and Radiation Division.

The study area included Midway Airport and the neighboring suburbs that is bordered on the north by Pershing Road, on the south by 70th Street, on the west by Harlem Avenue, and on the east by Pulaski Avenue. The area is approximately a 4-mile square grid (16 square miles) that is divided into 64 (8x8) rectangular grid cells. A total population of 93,845 resided in the study area.

The emission inventory included point sources, area sources, and mobile sources. The point source types included those traditionally inventoried in air pollution studies as well as some source types that are not traditionally inventoried such as volatilization from wastewater at sewage treatment plants; hazardous waste treatment, storage, and disposal facilities (TSDFs); abandoned hazardous waste sites; and landfills storing municipal waste. Using a broad emission inventory as the base inventory, the investigators searched the Toxic Release Inventory (TRI) database for new or additional sources to add to the inventory. Information from Resource Conservation and Recovery Act (RCRA) permits and Illinois EPA records were reviewed and six additional point sources were added to the inventory.

The inventory also included several area source categories such as road vehicles, gasoline marketing, barge loading, commercial and residential heating, residential wood combustion, dry cleaners, degreasing, surface coating, hospitals, paint strippers, demolition, chrome platers, and other area sources inventoried on a per capita basis. The mobile sources included road vehicles, nonroad engines, and aircraft engine emissions at Midway Airport. Aircraft engine emissions by aviation category from all phases of the landing and takeoff (LTO) cycle among all aircraft in 1990 were estimated. This study also considered the effects of carcinogenic air emissions from both point and area sources as far as 16 kilometers (10 miles) to the north of the Southwest Chicago receptor area.

This study used the Industrial Source Complex - Long Term (ISCLT) dispersion model and the Climatological Dispersion Model (CDM) for air dispersion modeling. These two dispersion models incorporated selected meteorological and emission inventory data to predict air pollutant concentrations in the receptor grid network. The ISCLT model was used for predicting concentrations from point sources and the CDM model was used for nonpoint or volume sources. The modeled ambient concentrations were based on the combination of the point source contribution, the nonpoint or volume source contribution, and the assumed background concentrations for formaldehyde and carbon tetrachloride. (Background formaldehyde results from photochemical reactions and background carbon tetrachloride results largely from atmospheric accumulation of "historical" emissions.) This study assumed background levels of 2.23 ug/m^3 for formaldehyde and 0.76 ug/m^3 for carbon tetrachloride, as documented in the Southeast Chicago study report. This assumption was made because these two areas are very close to each other. Risks due to background formaldehyde were added to these risks associated with directly emitted formaldehyde.

The study compared available monitored concentrations to modeled concentrations to assess the quality of model predictions. Monitored ambient concentrations for arsenic and cadmium were available for 1988 and 1991 in two locations. Monitored data for benzene, carbon tetrachloride, formaldehyde, methyl chloride, methylene chloride, perchloroethylene, styrene, and trichloroethylene were available for one location in the 1988/89 period. The study found that modeled concentrations generally are close to (e.g., on the same order of magnitude) or less than monitored concentrations. The investigators felt that the emission inventory might have underestimated emissions affecting the study area by either underestimating emissions at sources or failing to identify some sources of emissions.

Based on the estimated ambient concentrations, lifetime individual risks and lifetime cancer incidence were calculated for all pollutants and their contributing source categories at the receptors grid cells. The areawide cancer risk estimate within the study area was estimated by multiplying the lifetime individual risks in each receptor grid cell by the population in that grid cell and then summing the lifetime cancer cases over all 64 receptor grid cells from all pollutants and source categories.

Results: The study showed that the total number of cancer cases attributable to air pollution in this study area is about 20 cases over 70 years. Tables 3-1 and 3-2, adapted directly from the study, show the aggregated lifetime individual risks, aggregated lifetime cancer cases, and percent cancer cases by source category and by pollutant, respectively. Table 3-3 shows the pollutants attributed to road vehicles, background formaldehyde and carbon tetrachloride, chrome platers, nonroad mobile sources, and aircraft engines, which are the top five sources contributing to cancer cases. Table 3-4 shows the contributing source categories for 1,3-butadiene, POM, chromium VI, and formaldehyde, which are the top four pollutants causing cancers. The average lifetime individual risk across the area due to air pollution is approximately 2.1×10^{-4}.

Limitations: There are some limitations in this study. In terms of source category, this study may have underpredicted the cancer incidence caused by residential woodstoves and fireplaces because their cancer risks are two to three orders of magnitude lower than those in other urban air toxics studies. Because the modeled ambient air concentrations are generally less than the monitored concentrations, it is likely that some sources and pollutants were not captured in the inventory. This study may disproportionably emphasize airport emissions and the estimated risks because of the

Table 3-1. Aggregate Hazard Indices by Source Category[a]

Source Category	Lifetime Individual Risks	Lifetime Cancer Cases	Percent Cancer Cases
Road Vehicles[b]	3.34E-03	5.03	25.08
Background Concentration	2.58E-03	3.79	18.88
Chrome Platers	1.78E-03	3.13	15.60
Nonroad Engines	1.34E-03	2.14	10.65
Aircraft Engines	1.42E-03	2.11	10.52
Steel Mills	9.50E-04	1.41	7.03
Other Industrial Points	4.62E-04	0.68	3.41
Cooling Towers	3.00E-04	0.45	2.24
Residential Heating	1.99E-04	0.31	1.54
Gasoline Marketing	1.66E-04	0.26	1.28
Industrial Heating	9.47E-05	0.14	0.70
Wastewater Treatment	1.72E-04	0.13	0.63
Per Capita Area Sources	7.94E-05	0.12	0.62
Commercial Heating	7.94E-05	0.12	0.61
Degreasing	6.99E-05	0.10	0.52
Hospitals	3.27E-05	0.049	0.25
Dry Cleaners	2.54E-05	0.039	0.19
Paint Strippers	1.05E-05	0.016	-[c]
Other Hazardous Waste TSDFs	7.82E-06	0.012	-
Surface Coating	6.36E-06	0.010	-
Demolition	6.28E-06	0.0098	-
Residential Wood Combustion	2.96E-06	0.0044	-
Municipal Landfills	8.94E-07	0.0013	-
RCRA Hazardous Sites	2.28E-07	0.00034	-
Barge Loading	1.17E-07	0.00017	-

[a] Aggregated over all pollutants among all receptor grids

[b] Including vehicular emissions from parking lots and Helen Mikols Drive at Midway Airport

[c] "-" indicates less than 0.1%

Table 3-2. Aggregate Hazard Indices by Pollutants[a]

Pollutant	Individual Concentrations (ug/m^3)	Lifetime Individual Risks	Lifetime Cancer Cases	Percent Cancer Cases
1.3-Butadiene	1.09E+01	3.06E-03	4.69	23.36
POM[b]	1.24E+02	2.50E-03	3.78	18.83
Hexavalent Chromium	1.79E-01	2.15E-03	3.69	18.38
Formaldehyde	1.87E+02	2.44E-03	3.60	17.94
Coke Oven Emissions	1.30E+00	8.05E-04	1.20	5.96
Carbon Tetrachloride	4.87E+01	7.30E-04	1.07	5.33
Benzene	6.29E+01	5.22E-04	0.80	3.96
Arsenic	4.37E-02	1.88E-04	0.27	1.35
Gasoline Vapors	2.35E+02	1.55E-04	0.24	1.19
Ethylene Oxide	1.29E+00	1.29E-04	0.19	0.94
Hexachlorobenzene	3.68E-01	1.69E-04	0.13	0.66
Trichloroethylene	3.07E+01	5.22E-05	0.077	0.38
Perchloroethylene	8.12E+01	4.71E-05	0.074	0.37
Cadmium	2.36E-02	4.25E-05	0.062	0.31
Methylene Chloride	8.25E+01	3.88E-05	0.058	0.29
Chloroform	1.68E+00	3.86E-05	0.057	0.28
Asbestos	3.03E-03	2.30E-05	0.035	0.17
Dioxins	4.34E-07	1.43E-05	0.021	0.11
Vinyl Chloride	8.61E-02	7.23E-06	0.010	-[c]
Ethylene Dichloride	3.21E-01	8.34E-06	0.0087	-
Ethylene Dibromide	2.28E-02	5.02E-06	0.0067	-
Vinylidene Chloride	4.98E-02	2.49E-06	0.0038	-
Acrylonitrile	3.90E-02	2.65E-06	0.0037	-
Methyl Chloride	5.31E-01	9.56E-07	0.0015	-
Styrene	6.58E-01	3.75E-07	0.00041	-
Acrylamide	4.34E-05	5.64E-08	0.000083	-
Epichlorohydrin	3.51E-02	4.21E-08	0.000071	-
Propylene Oxide	8.46E-03	3.13E-08	0.000045	-
PCBs	8.76E-06	1.93E-08	0.000027	-
Beryllium	1.59E-06	3.82E-09	0.0000057	-

[a] Aggregated over all source categories among all receptor grids
[b] Aggregated over all inventoried POM emission sources
[c] "-" indicates less than 0.1%

Table 3-3. Top Five Source Contributors to Cancer Cases

Pollutant	Concentrations (ug/m^3)	Lifetime Individual Risks	Lifetime Cancer Cases
SOURCE CATEGORY - ROAD VEHICLES			
1,3-Butadiene	5.23E+00	1.46E-03	2.22
Diesel Particulate	6.68E+01	1.13E-03	1.69
Gasoline Particulate	5.93E+00	3.03E-04	0.46
Benzene	3.29E+01	2.73E-04	0.42
Formaldehyde	1.11E+01	1.45E-04	0.22
Asbestos	2.20E-03	1.67E-05	0.025
Cadmium	9.49E-04	1.71E-06	0.0026
SOURCE CATEGORY - BACKGROUND CONCENTRATIONS			
Formaldehyde	1.43E+02	1.86E-03	2.72
Carbon Tetrachloride	4.86E+01	7.30E-04	1.07
SOURCE CATEGORY - CHROME PLATERS			
Hexavalent Chromium	1.48E-01	1.78E-03	3.13
SOURCE CATEGORY - NONROAD MOBILE SOURCES			
1,3-Butadiene	2.68E+00	7.52E-04	1.19
Diesel Particulate	2.69E+01	4.57E-04	0.73
Gasoline Particulate	3.36E+00	5.38E-05	0.085
Benzene	6.39E+01	5.31E-05	0.084
Formaldehyde	2.27E+01	2.95E-05	0.047
SOURCE CATEGORY - AIRCRAFT ENGINES			
1,3-Butadiene	2.87E+00	8.03E-04	1.21
Formaldehyde	2.38E+01	3.09E-04	0.47
Turbine Particulate	1.63E+01	2.76E-04	0.39
Benzene	3.40E+00	2.82E-05	0.041
Piston Particulate	4.61E-01	7.37E-06	0.0082

Table 3-4. Top Four Pollutant Contributors to Cancer Cases

Source Category	Concentrations (ug/m^3)	Lifetime Individual Risks	Lifetime Cancer Cases
POLLUTANT - 1,3-BUTADIENE			
Road Vehicles	5.23E+00	1.46E-03	2.22
Aircraft Engines	2.87E+00	8.03E-04	1.21
Nonroad Engines	2.68E+00	7.52E-04	1.19
Other Industrial Points	1.54E-01	4.30E-05	0.071
Other Hazardous Waste TSDFs	3.88E-03	1.09E-06	0.0018
Steel Mills	3.29E-04	9.20E-08	0.00014
POLLUTANT - POM/Particulate Matter			
Road Vehicles	7.27E+01	1.43E-03	2.15
Diesel Particulate	*6.68E+01*	*1.13E-03*	*1.69*
Gasoline Particulate	*5.93E+00*	*3.03E-04*	*0.46*
Nonroad Engines	3.03E+01	5.11E-04	0.82
Diesel Particulate	*2.69E+01*	*4.57E-04*	*0.73*
Gasoline Particulate	*3.36E+00*	*5.38E-05*	*0.085*
Aircraft Engines	1.68E+01	2.83E-04	0.40
Piston Particulate	*1.63E+01*	*2.76E-04*	*0.39*
Turbine Particulate	*4.61E-01*	*7.37E-06*	*0.0082*
Others POM Sources (B(a)P Surrogate)	1.37E-01	2.32E-04	0.35
Residential Heating (Distillate Oil Use)	4.24E+00	3.82E-05	0.059
Woodstoves	1.02E-01	2.96E-06	0.0044

continued.....

Table 3-4. Top Four Pollutant Contributors to Cancer Cases (continued)

Source Category	Concentrations (ug/m^3)	Lifetime Individual Risks	Lifetime Cancer Cases
POLLUTANT - HEXAVALENT CHROMIUM			
Chrome Platers	1.48E-01	1.78E-03	3.13
Cooling Towers	2.50E-02	3.00E-04	0.45
Commercial Heating	3.14E-03	3.77E-05	0.058
Residential Heating	1.57E-03	1.88E-05	0.029
Industrial Heating	8.79E-04	1.06E-05	0.016
Steel Mills	1.69E-04	2.03E-06	0.0030
Other Industrial Points	1.72E-04	2.06E-06	0.0030
RCRA Hazardous Sites	1.34E-09	1.60E-11	0.00000002
POLLUTANT - FORMALDEHYDE			
Background Concentrations	1.43E+02	1.86E-03	2.72
Aircraft Engines	2.38E+01	3.09E-04	0.47
Road Vehicles	1.11E+01	1.45E-04	0.22
Per Capita Area Sources	2.50E+00	3.25E-05	0.051
Residential Heating	2.49E+00	3.24E-05	0.050
Nonroad Engines	2.27E+00	2.95E-05	0.047
Other Industrial Points	2.03E+00	2.64E-05	0.037
Commercial Heating	2.47E-01	3.21E-06	0.0049
Industrial Heating	1.84E-01	2.39E-06	0.0036
Steel Mills	5.00E-02	6.51E-07	0.00098
Other Hazardous Waste TSDFs	1.77E-04	2.31E-09	0.0000034

configuration of the study grid around Midway Airport. The reader should note that the lifetime individual risks and concentrations expressed in the tables excerpted from the SW Chicago study are not averaged over the receptor grid, but rather, are the sum of the risks or concentrations across all 64 grid cells in the receptor grid. Hence, the values in these tables do not make physical sense, per se, and should not be construed as representative of any particular grid cell at all or indicative of the average lifetime cancer risk across the study area.

Many of the general assumptions and limitations itemized in Section 2.5 apply to this study.

3.2 IEMP-Baltimore II Study[7]

Report Title/Date: Baltimore Integrated Environmental Management Project: Phase II, Ambient Air Toxics Report, EPA/230-R-92-013, February 1992

Conducted by: U.S. EPA, Office of Policy, Planning and Evaluation

Background and Methodology: The Baltimore Integrated Environmental Management Project (IEMP) Ambient Air Toxics Study was conducted to assist EPA and local officials in exploring better ways to identify, assess, and manage the human health risks of environmental pollutants in the area. This study estimated the increases in cancer and noncancer risks resulting from exposure to ambient air toxics. The air toxics study was designed to test a new approach (using cancer potency-weighted ambient concentrations) in the screening to set research and control priorities among sources and pollutants contributing to the complex mixture of ambient air toxics in the Baltimore area. This study was originally reported in Cancer Risk...[1], but was further modified and was thus treated as a new study in this report.

The study area included the City of Baltimore, the southern half of Baltimore County, and the northern part of Anne Arundel County. The study area was subdivided into 64 (8x8) 5-km squares grid cells. Another refined grid consisting of 64 (8x8) 2.5-km grid cells overlaid the most densely populated portion of the study area. The 1980 population of 1.6 million was used for the study area.

The emission inventory covered more than 200 pollutants, but only a small number of compounds were selected for evaluation in the Baltimore air toxics study. The first set of pollutants included 12 organic gases, 2 organic particulates, and 3 metals for the cancer effect assessment. Another set of 22 volatile organics and 1 metal was evaluated for a noncancer effect assessment. A majority of the pollutants showed up in both the cancer and noncancer effect lists. The emission inventory included approximately 250 point sources, area sources, and nontraditional sources. The point source emission inventory was based on a 1985 survey which included a limited number of pollutants and sources where hazardous materials were used, produced, or handled. The area sources included motor vehicles, gasoline service stations, solvent usage by commercial and small industrial facilities, heating (i.e., industrial, commercial, institutional, and residential), waste oil combustion, agricultural burning, and minor point sources not modeled individually. Nontraditional sources included cooling towers, trihalomethane volatilization from drinking water distribution, and sewage treatment plants. The investigators calculated emissions from these area sources using an assortment of emission factors and algorithms developed by EPA's Regulatory Integration Division and Office of Air and Radiation. Total hydrocarbon emissions from cars and trucks were estimated using EPA's MOBILE3 computer model and then subsequently speciated into specific toxic pollutants.

The Industrial Source Complex - Long Term (ISCLT) dispersion model and the Climatological Dispersion Model (CDM) were used for air dispersion modeling. These two dispersion models incorporated selected meteorological and emission inventory data to predict air pollutant concentrations in the receptor grid network. The ISCLT model was used for predicting concentrations from point sources and the CDM model was used for area sources. Atmospheric transformation of formaldehyde and long-term accumulation of carbon tetrachloride were not considered in this study.

In addition to doing a modeling analysis, this study also used available monitoring data from studies conducted in the Baltimore area from 1983 through 1987.

In the Baltimore IEMP, a relative ranking of pollutants and sources was developed using two approaches. First, at the recommendation of a risk assessment panel from Johns Hopkins, a ranking of pollutants and sources was developed by cancer potency-weighted ambient concentrations. This approach was recommended because it avoids relying on highly uncertain exposure assumptions used in many screening assessments and does not incorporate population weighting factors. A second approach consisted of conducting a quantitative risk assessment for the pollutants and sources examined, considering both cancer and noncancer effects.

Results - Ranking by Cancer Potency-Weighted Ambient Concentrations: In this approach, the investigators calculated the average areawide modelled concentration of each target pollutant using the 5 km modelling grid system and then multiplied this value by the pollutant's corresponding unit cancer risk factor. The product is a measure of each pollutant's potential human health risk in the Baltimore area. Pollutants were compared and ranked by normalizing against the cancer potency-weighted concentration for one of the more common pollutants in the ambient air -- chloroform. Table 3-5, adapted directly from the study, shows the relative ranking of target compounds by cancer potency-weighted ambient concentrations determined from dispersion models. POM ranked highest with a score approximately four times higher than the next highest pollutant, chromium, and roughly twice as high as the summed scores for all other pollutants. Carbon tetrachloride ranked lowest of all pollutants.

To rank sources under this approach, the investigators first summed the potency-weighted average concentrations resulting from each source or source category and then normalized against the value for gasoline marketing. Again, the potency-weighted concentration is simply a measure of the potential risk to human health posed by a source or source category in the Baltimore area. Table 3-6 shows the relative significance of point sources and area sources based on this ranking. [Note: area sources are not defined in this study per the Section 112 10/25 TPY cutoff.]

Results - Based on Population-based Cancer Risk Assessment Screening: In the modeling analysis, the investigators calculated the average area-wide increased cancer risk by (1) multiplying the estimated average ambient air concentration by pollutant for each 5 km grid cell by the appropriate unit cancer risk factor, (2) calculating an arithmetic average across all grid cells and (3) summing across all pollutants. A similar analysis was performed using monitoring data, substituting monitoring data for model-projected data.

The study presented both average increased lifetime individual cancer risk and annual excess cancer incidence based on modeled and monitored ambient concentrations. The average increased lifetime individual cancer risks using modeled data and monitored data were 1.5×10^{-4} and 5.2×10^{-4}, respectively. Table 3-7 shows the total and pollutant-specific average increased lifetime individual cancer risks using the available monitored data for the Baltimore area. Three pollutants account for most (about 87 percent) of the estimated average increased lifetime individual cancer risk: perchloroethylene (48 percent), hexavalent chromium (24 percent) and benzene (15 percent).

Table 3-5. Relative Ranking of Target Compounds by Cancer Potency-Weighted Ambient Concentrations

POLLUTANT	UNIT CANCER RISK FACTOR	AVERAGE CONCENTRATION (ug/m3) (1)	POTENCY-WEIGHTED CONCENTRATIONS	RATIO OF POTENCY-WEIGHTED CONCENTRATIONS (Chloroform = 1)
POM	6.50E-05	1.4865625	9.66E-05	151.9
CHROMIUM-6	1.20E-02	0.0015625	1.88E-05	29.5
BENZENE	8.00E-06	1.115625	8.93E-06	14.0
FORMALDEHYDE	1.30E-05	0.446875	5.81E-06	9.1
METHYLENE CHLORIDE	4.10E-06	1.4	5.74E-06	9.0
ARSENIC	4.30E-03	0.0013125	5.64E-06	8.9
CADMIUM	1.80E-03	0.0014375	2.59E-06	4.1
PERCHLOROETHYLENE	4.80E-07	2.33	1.12E-06	1.8
TRICHLOROETHYLENE	1.30E-06	0.7234375	9.40E-07	1.5
CHLOROFORM	2.30E-05	0.02765625	6.36E-07	1.0
ETHYLENE DICHLORIDE	2.60E-05	0.005390625	1.40E-07	0.2
ETHYLENE DIBROMIDE	2.20E-04	0.000515625	1.13E-07	0.2
ETHYLENE OXIDE	1.00E-04	0.000875	8.75E-08	0.1
CARBON TETRACHLORIDE	3.70E-06	0.00015625	5.78E-10	0.0

(1) Modelled concentration

Table 3-6. Relative Ranking of Sources by Contribution to Cancer Potency-Weighted Ambient Concentrations

SOURCE	POLLUTANT	UNIT CANCER RISK FACTOR	AVERAGE CONCEN-TRATION (ug/m3) (1)	POTENCY-WEIGHTED CONC.	SUM OF POTENCY-WEIGHTED CONC.	RATIO OF SOURCES (gas mrktng=1)
Point sources:						
Point Source A	POM	6.50E-05	0.86406	0.0000562	0.0000905	489
	Chrom.-6	1.20E-02	0.00245	0.0000294		
	Benzene	8.00E-06	0.60625	0.0000049		
Point Source B	Chrom.-6	1.20E-02	0.00027	0.0000033	0.0000033	18
Point Source C	Chrom.-6	1.20E-02	0.00026	0.0000031	0.0000031	17
Point Source D	Chrom.-6	1.20E-02	0.00011	0.0000013	0.0000013	7
Area sources:						
Road vehicles	POM	0.00005	0.11494	0.0000057	0.0000126	68
	Frmldhyde	1.30E-05	0.27422	0.0000036		
	Benzene	8.00E-06	0.41250	0.0000033		
Solvent usage	Met. CL	4.10E-06	1.34609	0.0000055	0.0000067	36
	PERC	4.80E-07	0.68156	0.0000003		
	TCE	1.30E-06	0.68000	0.0000009		
Heating	POM	0.00001	0.45625	0.0000046	0.0000101	55
	Arsenic	4.30E-03	0.00088	0.0000038		
	Cadmium	1.80E-03	0.00100	0.0000018		
Gas marketing	Benzene	8.00E-06	0.02313	0.0000002	0.0000002	1

(1) Modelled concentration.

Table 3-7. Average Increased Lifetime Individual Cancer Risk Using Available Monitoring Data (1, 2)

RESULTS INTENDED FOR POLICY DEVELOPMENT ONLY

POLLUTANT [Weight of Evidence]	AVERAGE INCREASED LIFETIME INDIVIDUAL CANCER RISK
Arsenic [B1]	7.0E-06
Benzene [A]	7.5E-05
Benzo(a)pyrene [B2]	2.5E-06
Cadmium [B1]	2.2E-06
Carbon tetrachloride [B2]	3.4E-06
Chloroform [B2]	3.2E-05
Chromium VI [A]	1.2E-04
Ethylene dichloride [B2]	1.6E-05
Propylene dichloride [C]	8.6E-06
Ethyl benzene [N/A]	N/A
Lead [N/A]	N/A
Methylene chloride [B2]	9.8E-06
Methyl isobutyl ketone [N/A]	N/A
Perchloroethylene [B2]	2.4E-04
Toluene [N/A]	N/A
Methyl chloroform [N/A]	N/A
Trichloroethylene [B2]	1.1E-06
Vinyl chloride [A]	N/A
Xylene [N/A]	N/A
TOTAL	5.2E-04

N/A: Not Applicable

(1) Source of monitoring data: See Appendix B.

(2) This study uses conservative estimates of increased cancer risk from ambient (i.e., outdoor) exposure to establish priorities among pollutants and sources. The risk estimates are calculated using modelled or monitored concentrations and EPA unit cancer risk factors. There is considerable uncertainty in the estimated concentrations, which could either overstate or understate the true concentrations (see Chapter IV). Unit cancer risk factors combine CAG potency estimates with EPA exposure assumptions. The CAG potency estimates provide a plausible upper limit to the cancer risk of a compound (see Appendix A); however, the true value of the risk is unknown and may be as low as zero. The exposure assumptions are extremely conservative in that they assume continuous exposure to outdoor air for 70 years. Because of the generally conservative bias in the information, it is highly unlikely that the true risks would be as high as the estimates and they could be considerably lower.

Table 3-8 shows that annual excess cancer incidence using modeled concentrations for the top 14 pollutants was 3.56 cases/year. Almost all of the estimated annual excess cancer incidence (about 94 percent) can be attributed to six pollutants: POM, chromium +6, methylene chloride, benzene, arsenic, and formaldehyde. Most of the incidence (57 percent) is from POM alone.

Table 3-9 shows that the annual excess cancer incidence using available monitored data for the top 12 pollutants was 11.79 cases/yr. The difference in the predicted annual excess cancer incidence from modeled and monitored data was explained by a significantly higher incidence estimated for perchloroethylene, chromium VI, and benzene based on monitored data.

Results - Based on Noncancer Screening: For noncancer effects, the study divided the modeled and monitored concentration by the no-effect thresholds of those noncancer effects (e.g., liver toxicity, kidney toxicity, reproductive, neurological, fetal, or blood) relevant to the pollutant. If the resulting ratio exceeded one, the specific pollutant was identified for additional investigation. Table 3-10 shows the potential for blood effects for benzene at several receptor locations and the multiple effects for xylene at one receptor location warranting further investigation.

For the noncancer impact of exposure to complex chemical mixtures in the ambient air, the study used a hazard index that summed individual pollutant ratios by the effect category. If the hazard index exceeded one, the exposures to the complex chemical mixtures deserved further analysis. As shown in Table 3-11, this study found that benzene is the primary pollutant of potential noncancer concern at several discrete receptor locations.

Limitations: This study failed to account for background concentrations imported from outside the study area or formed by chemical transformation. The emission inventory also potentially underestimated the point and area source emissions in the study area. Comparing the pollutants included in this study with those in other studies, it was found that this study covered most of the pollutants causing the highest number of cancer risks except for 1,3-butadiene and gasoline vapor. Gasoline vapor and 1,3-butadiene are primarily emitted from gasoline marketing and mobile sources, respectively. Also, the study did not include chrome platers or cooling towers as major chromium VI emitters, but attributed chromium VI emissions to four major point sources.

As shown in Table 3-12, the study compared the predicted average lifetime individual cancer risk for several pollutants in the Baltimore area with those in other studies. This comparison shows that the predicted cancer risks for all pollutants are generally in the same range as or lower than those in other studies. The investigators felt the differences in modeling assumptions regarding release specifications and receptor placement can significantly affect predictions of lifetime individual cancer risks. Underestimated emissions also contributed to the lower cancer risk incidence predicted.

Modeled concentrations for 10 pollutants at the locations corresponding to 10 monitoring sites were compared. For all pollutants considered, except trichloroethylene, the models consistently underpredicted ambient air concentrations. The investigators felt the bias for the modeling could be attributed to (1) a potential underestimation of the point and area source emissions, (2) failure to account for background concentrations imported from outside the study area or by chemical transformation, or (3) the treatment of atmospheric and meteorological conditions in the dispersion models. Although the exposure estimates based on modeling were understated; the investigators felt the estimates of risk using these modeled values were still more likely to overstate than understate

Table 3-8. Estimated Annual Excess Cancer Incidence for Selected Pollutants Modelled in the Baltimore IEMP Air Toxics Study (total study area, 5 km grid system) [1]

RESULTS INTENDED FOR POLICY DEVELOPMENT ONLY

POLLUTANT	ANNUAL EXCESS CANCER INCIDENCE (Weight of Evidence)	PERCENTAGE OF TOTAL
Polycyclic organic matter (POM)[2]	2.05 (N.A.)	57.4
Chromium (VI)	0.53 (A)	14.8
Methylene chloride	0.20 (B2)	5.6
Benzene	0.20 (A)	5.6
Arsenic	0.20 (A)	5.6
Formaldehyde	0.19 (B1)	5.3
Cadmium	0.09 (B1)	2.5
Perchloroethylene (PCE)	0.04 (B2)	1.1
Trichloroethylene (TCE)	0.03 (B2)	0.8
Chloroform	0.02 (B2)	0.6
Ethylene dichloride (EDC)	0.01 (B2)	0.3
Ethylene dibromide (EDB)	<0.01 (B2)	0.1
Benzo(a)pyrene (B(a)P)	<0.01 (B2)	<0.1
Carbon tetrachloride	<0.01 (B2)	<0.1
TOTAL[3]	3.56	100.0

N.A. = Not Available

[1] This study uses conservative estimates of increased cancer risk from ambient (i.e., outdoor) exposure to establish priorities among pollutants and sources. The risk estimates are calculated using modelled or monitored concentrations and EPA unit cancer risk factors. There is considerable uncertainty in the estimated concentrations, which could either overstate or understate the true concentrations (see Chapter IV). Unit cancer risk factors combine CAG potency estimates with EPA exposure assumptions. The CAG potency estimates provide a plausible upper limit to the cancer risk of a compound (see Appendix A); however, the true value of the risk is unknown and may be as low as zero. The exposure assumptions are extremely conservative in that they assume continuous exposure to outdoor air for 70 years. Because of the generally conservative bias in the information, it is highly unlikely that the true risks would be as high as the estimates, and they could be considerably lower.

[2] The POM risk estimates are, in part, based on source-specific unit cancer potency factors that have not undergone extensive peer review. Thus, these numbers are subject to change.

[3] Totals may not sum because of rounding.

Table 3-9. Area-Wide Annual Excess Cancer Incidence Using Available Monitoring Data (1, 2)

RESULTS INTENDED FOR POLICY DEVELOPMENT ONLY

POLLUTANT [Weight of Evidence]	ANNUAL EXCESS CANCER INCIDENCE	ANNUAL EXCESS CANCER INCIDENCE
Arsenic [B1]	0.16	0.20
Benzene [A]	1.72	0.20
Benzo(a)pyrene [B2]	0.06	<0.01
Cadmium [B1]	0.05	0.09
Carbon tetrachloride [B2]	0.08	<0.01
Chloroform [B2]	0.73	0.02
Chromium VI [A]	2.74	0.53
Ethylene dichloride [B2]	0.37	0.01
Propylene dichloride [C]	0.20	N.A.
Ethyl benzene [N/A]	N/A	N/A
Lead [N/A]	N/A	N/A
Methylene chloride [B2]	0.22	0.20
Methyl isobutyl ketone [N/A]	N/A	N/A
Perchloroethylene [B2]	5.44	0.04
Toluene [N/A]	N/A	N/A
Methyl chloroform [N/A]	N/A	N/A
Trichloroethylene [B2]	0.03	0.03
Vinyl chloride [A]	N/A	N.A.
Xylene [N/A]	N/A	N/A
TOTAL	11.79	1.32

N/A: Not applicable; not a proven human carcinogen
N.A.: Not available

(1) Source of monitoring data: See Appendix B.

(2) This study uses conservative estimates of increased cancer risk from ambient (i.e., outdoor) exposure to establish priorities among pollutants and sources. The risk estimates are calculated using modelled or monitored concentrations and EPA unit cancer risk factors. There is considerable uncertainty in the estimated concentrations, which could either overstate or understate the true concentrations (see Chapter IV). Unit cancer risk factors combine CAG potency estimates with EPA exposure assumptions. The CAG estimates provide a plausible upper limit to the cancer risk of a compound (see Appendix A); however, the true value of the risk is (see Appendix A); however, the true value of the risk is unknown and may be as low as zero. The exposure assumption are extremely conservative in that they assume continuous exposure to outdoor air for 70 years. Because of the generally conservative bias in the information, it is highly unlikely that the true risks would be as high as the estimates, and they could be considerably lower.

Table 3-10. Receptor Locations Warranting Further Investigation for Noncancer Effects: Pollutant-Specific (1)

RESULTS INTENDED FOR POLICY DEVELOPMENT ONLY

RECEPTOR LOCATION		CONCENTRATION TO THRESHOLD RATIO (2)	POLLUTANT OF CONCERN	NONCANCER EFFECT (3)
REFINED GRID				
4342.25	364.75	1.1	BENZENE	BLOOD
4342.25	367.25	1.6	BENZENE	BLOOD
4342.25	369.75	5.0	BENZENE	BLOOD
4342.75	364.75	1.3	BENZENE	BLOOD
4342.75	367.25	1.1	BENZENE	BLOOD
4342.75	369.75	1.4	BENZENE	BLOOD
DISCRETE SITE				
4339.85	374.88	1.7	BENZENE	BLOOD
4340.22	374.95	1.6	BENZENE	BLOOD
4340.65	375.10	1.3	BENZENE	BLOOD
4340.85	375.31	1.2	BENZENE	BLOOD
4341.15	375.30	1.2	BENZENE	BLOOD
4341.41	375.30	1.1	BENZENE	BLOOD
4342.00	374.25	1.3	BENZENE	BLOOD
4342.52	374.00	1.2	BENZENE	BLOOD
4343.00	374.12	1.1	BENZENE	BLOOD
4343.15	373.90	1.1	BENZENE	BLOOD
4350.92	370.55	1.5	XYLENE	LIVER
4350.92	370.55	1.5	XYLENE	KIDNEY
4350.92	370.55	6.2	XYLENE	REPRODUCTIVE
4350.92	370.55	1.5	XYLENE	NEUROLOGICAL
4350.92	370.55	6.2	XYLENE	FETAL/DEVELOPMEN
4350.92	370.55	1.5	XYLENE	BLOOD

(1) The noncancer effects analysis did not consider personal exposures (e.g., indoor and work).

(2) The threshold values underlying these ratio calculations are based on data of uneven quality. Furthermore, exceedance of a threshold value of greater than one does not necessarily indicate severity of effect; it simply indicates the need to further explore these exposure levels. For the purpose of this study, it was assumed that a ratio greater than or equal to 0.95 was equivalent to "1" through rounding.

(3) The blood effect thresholds for benzene and xylene have not yet undergone peer review, thus the results are subject to change.

Table 3-11. Receptor Locations Warranting Further Investigation for Noncancer Effects: Complex Pollutant Mixtures (1)

RESULTS INTENDED FOR POLICY DEVELOPMENT ONLY

DISCRETE RECEPTOR LOCATION		HAZARD INDEX (2)	PRIMARY POLLUTANT OF CONCERN (RATIO VALUE)	NONCANCER EFFECT
4342.93	362.98	1.0	BENZENE (0.92)	BLOOD
4343.20	362.95	1.0	BENZENE (0.92)	BLOOD
4343.45	362.78	1.0	BENZENE (0.94)	BLOOD
4343.58	362.55	1.0	BENZENE (0.93)	BLOOD
4343.70	362.28	0.96	BENZENE (0.88)	BLOOD
4346.27	367.88	1.0	BENZENE (0.93)	BLOOD
4346.68	367.77	0.95	BENZENE (0.87)	BLOOD

(1) The noncancer effects analysis did not consider personal exposures (e.g., indoor and work).

(2) The threshold values underlying these hazard indexes are based on data of uneven quality. Furthermore, exceedance of a threshold value or a hazard index of greater than one does not necessarily indicate severity of effect; it simply indicates the need to further investigate these exposure levels. For the purpose of this study, it was assumed that a ratio greater than or equal to 0.95 was equivalent to "1" through rounding. The hazard index represents the sum of all pollutant-specific ratios with the same systemic effect at a particular location.

(3) The blood effect threshold for benzene has not yet undergone peer review, thus the results are subject to change.

Table 3-12. A Comparison of Predicted Average Lifetime Individual Cancer Risk in Baltimore with Other Studies

RESULTS INTENDED FOR POLICY DEVELOPMENT ONLY

POLLUTANTS (WEIGHT OF EVIDENCE)	NESHAPS STUDY	35 COUNTY STUDY	AMBIENT AIR QUALITY STUDY	SOUTH COAST STUDY	SANTA CLARA IEMP	KANAWHA IEMP	PHILA IEMP	BALT STUDY
Arsenic [A]	1.4E-06	1.4E-05	1.8E-05	1.0E-09	1.5E-05	1.3E-05		8.6E-06
Benzene [A]	9.8E-06	2.7E-05	7.6E-05	3.9E-04	2.0E-05	2.9E-05	1.9E-05	8.7E-06
Benzo-a-pyrene [B2]		1.4E-06	1.4E-06			4.3E-06		9.9E-09
Cadmium [B1]	4.9E-06	1.4E-06	4.2E-06	6.7E-06	4.0E-06	2.0E-06		3.8E-06
Carbon Tet. [B2]	4.2E-06	2.8E-07	2.6E-05	1.0E-08	1.0E-05	1.5E-05	1.5E-06	3.7E-09
Chloroform [B2]	<7.00E-07	2.1E-07	3.2E-05		6.0E-08	1.4E-04	4.6E-06	9.0E-07
Chromium VI [A]	7.7E-06	2.0E-05	7.4E-05	7.1E-04	2.0E-05			2.2E-05
1,2Dichloro-ethane [B2]	1.3E-05	2.8E-06					2.6E-06	2.1E-07
Ethylene Dibromide [B2]	8.4-06	1.4E-06		5.0E-08	2.0E-07			1.7E-07
Ethylene Oxide [B1]	1.5E-05				2.0E-06	5.9E-04		8.4E-08
Formaldehyde[B1]	<7.00E-07	1.5E-05	5.8E-05					8.1E-06
Methylene Chloride [B2]				2.4E-05	6.0E-07	2.6E-05		8.7E-06
Perchloro-ethylene [C]	<7.00E-07	9.8E-06	7.7E-06	3.0E-06	2.0E-06	1.5E-06	1.7E-06	1.7E-06
POMs [N.A.]	2.8E-06							8.9E-05
Trichloro-ethylene [B2]		1.1E-05	7.7E-06		1.0E-07	1.8E-06	1.3E-06	1.5E-06

true risk. This conclusion was drawn because of the generally conservative bias in the underlying data and assumptions used in the risk assessment.

Many of the general assumptions and limitations itemized in Section 2.5 apply to this study.

3.3 The Detroit Study[12]

Report Title/Date: The Transboundary Air Toxics Study: Final Summary Report, December, 1990

Conducted by: Engineering-Science, Inc. for U.S. EPA Region 5, Air and Radiation Division

Background and Methodology: The purpose of the Transboundary Air Toxics Study was twofold. The primary purpose of the study was to evaluate the health risks of non-criteria, toxic air pollutants on urban populations. The second purpose of the study was to estimate the relative impact that atmospheric deposition of these toxic substances has on the ecosystem of the Great Lakes area. The remainder of this summary will not address the deposition assessment but, instead, will only deal with the risk analysis portion of the study.

This study serves to evaluate the pollutants which contribute to increased cancer risks and the relative contributions of various source types to that increased risk in the Transboundary area. The study area focused on the counties that include the industrialized areas within the region. A total of 10 counties (7 in Michigan and 3 in Ontario) were chosen to be included. The study area has a population of 4,285,000 (499,000 on the Canadian side of the border) and a mix of industrial and other urban sources. The area was limited to roughly 50 kilometers (km) from Lake St. Clair and the Detroit and St. Clair Rivers due to the types of modeling techniques planned. The grid system employed is the same as that developed for the National Acid Precipitation Assessment Program (NAPAP) inventory. The grid cells for the NAPAP inventory were 20 km on a side (square) but for this study were further divided into smaller grid cells (10 km, 5 km, and 2.5 km), for a total of 384 cells, to provide greater detail to the study.

Several criteria were chosen to identify the pollutants to investigate in this study. Generally, the pollutants chosen were substances known to be atmospherically deposited into the region or substances known to pose a carcinogenic risk or other significant human health risk. A total of 57 substances was decided on. Based on the types of source categories that produce these 57 substances, a list of point and area sources was developed. Table 3-13 lists these source categories and breaks them down between point sources and area sources.

The initial source for emissions data was the volatile organic compound (VOC) and total suspended particulate (TSP) emissions inventory from EPA's National Acid Precipitation Assessment Program (NAPAP). Other data sources that were utilized included databases from EPA (including the NESHAP's database) and other government agencies from both the U.S. and Canada. The EPA's Air Emissions Species Manual provided emissions profile data for each source category. From these sources, specific pollutant emissions were estimated and modeled.

Once the emissions inventory was prepared, air dispersion modeling proceeded. The Industrial Source Complex-Long Term (ISCLT) Model was used for air dispersion modeling of both point sources and area sources for this study. Meteorological data was taken from Detroit Metropolitan Airport for the years 1982-1986. Background concentrations were assumed to be zero except for formaldehyde (assumed to be 2.23 $\mu g/m^3$) and carbon tetrachloride (assumed to be 0.76 $\mu g/m^3$). These background concentrations were adopted from the Southeast Chicago study.

Table 3-13. Summary of Source Categories

Point Sources
Chemical production
Coke and charcoal combustion
Coke ovens/iron and steel
Fuel combustion
Metals production
Motor vehicle manufacturing
Refineries
Waste incineration
Area Sources
Additional miscellaneous NAPAP categories
Architectural coatings
Auto refinishing
Cold degreasing
Cooling towers
Dry cleaning
Gasoline marketing
Mobile sources
Pesticides
Residential oil combustion
Residential wood combustion

Unit risk factors for the specific pollutants were obtained from several different EPA offices and 16 of these risk factors have received agency-wide review. The unit risk factors used in this study reflect the best judgements of the EPA scientists, however, the uncertainties in the unit risk factors are probably the greatest uncertainties in the study.

Cancer risk at a given location was estimated by multiplying, for each pollutant, the modeled concentration times the unit risk factor of that pollutant, and then summing for all pollutants. Excess cancer incidence is a population-oriented measure. By multiplying the risk in a given area times the population of that area, an estimate of the number of excess cancer cases is obtained.

Results: Of the 57 pollutants initially considered, this study found atmospheric emissions of 27 pollutants which EPA considers carcinogenic and 15 pollutants which EPA does not consider carcinogenic. This study suggests that for the study area, roughly 373 cancer cases over 70 years (or slightly over 5 cases per year) can be attributed to air pollution. The average lifetime risk across the entire study area is estimated at roughly $9x10^{-5}$.

Table 3-14 provides a summary of additional cancer incidence, by pollutant, for a 70 year exposure period. Figure 3-1 shows the percentage of total excess cancer incidence can be attributed to the individual pollutants. As can be seen from Figure 3-1, over 90 percent of the predicted excess cancer incidence results from 7 specific pollutants: formaldehyde, coke oven emissions, 1,3-butadiene, carbon tetrachloride, hexavalent chromium, total polycyclic organic matter, and dioxins. The largest single contributor is formaldehyde (36.1 percent). Most of this formaldehyde is due to background concentrations from photochemical generation.

The next largest contributors to total predicted incidence are coke oven emissions, 1,3-butadiene, and carbon tetrachloride. Coke oven emissions are from one particular source (steel and coke manufacturing). Motor vehicles are the major contributor for 1,3-butadiene, while carbon tetrachloride is primarily a background pollutant, due to historical emissions that have accumulated in the atmospheric over the years because of carbon tetrachloride's low reactivity.

The next most important contributors to increased cancer incidence are hexavalent chromium, polycyclic organic matter (POM), and dioxins. While hexavalent chromium is emitted from many source categories, almost half of the hexavalent chromium in this study came from chrome plating operations. Dioxins and POM come from a variety of fuel combustion sources. The remaining cancer incidence (roughly eight percent) results from the other 20 carcinogenic pollutants identified in the study and from the various source categories.

All emissions were divided among eight broad source groupings: photochemical generation, vehicle manufacturing, steel/coke manufacturing, other manufacturing, highway vehicles, fuel combustion, background concentrations, and residential/miscellaneous. Figure 3-2 presents the cancer incidence attributable to each of these source groupings.

Cancer incidence and individual risk results were also presented for the grid cell of maximum risk on both the U.S. and Canadian sides of the border and for the entire study area. A lifetime cancer risk of $1.2x10^{-4}$ is estimated for this particular grid cell. Tables 3-15 and 3-16 present the contributions by pollutant and source groupings to the risks in the peak risk area. These tables show the relative importance of coke oven emissions over other pollutants and source groupings at the peak risk area.

Table 3-14. Summary of Estimated Excess Cancer Cases by Pollutant Across the Study Area

Substance	Total
Formaldehyde	134.7
Coke oven emissions	61.0
1,3 butadiene	56.5
Carbon tetrachloride	52.1
Chromium	13.5
POM	12.3
Dioxins	12.0
Arsenic	7.4
Beryllium	5.8
Asbestos	5.7
Benzene	5.0
Gasoline vapors	3.0
Cadmium	1.4
Benzo(a)pyrene	0.7
Ethylene dibromide	0.6
Vinyl chloride	0.4
Trichloroethylene	0.3
Perchloroethylene	0.2
PCBs	0.1
Styrene	0.1
All others*	0.1
TOTAL	372.9

*Chloroform, ethylene oxide, acrylonitrile, methylene chloride, chlordane, heptachlor, and epichlorohydrin.

Figure 3-1. Estimated Excess 70-Year Incidence, Area Wide by Pollutant Contribution

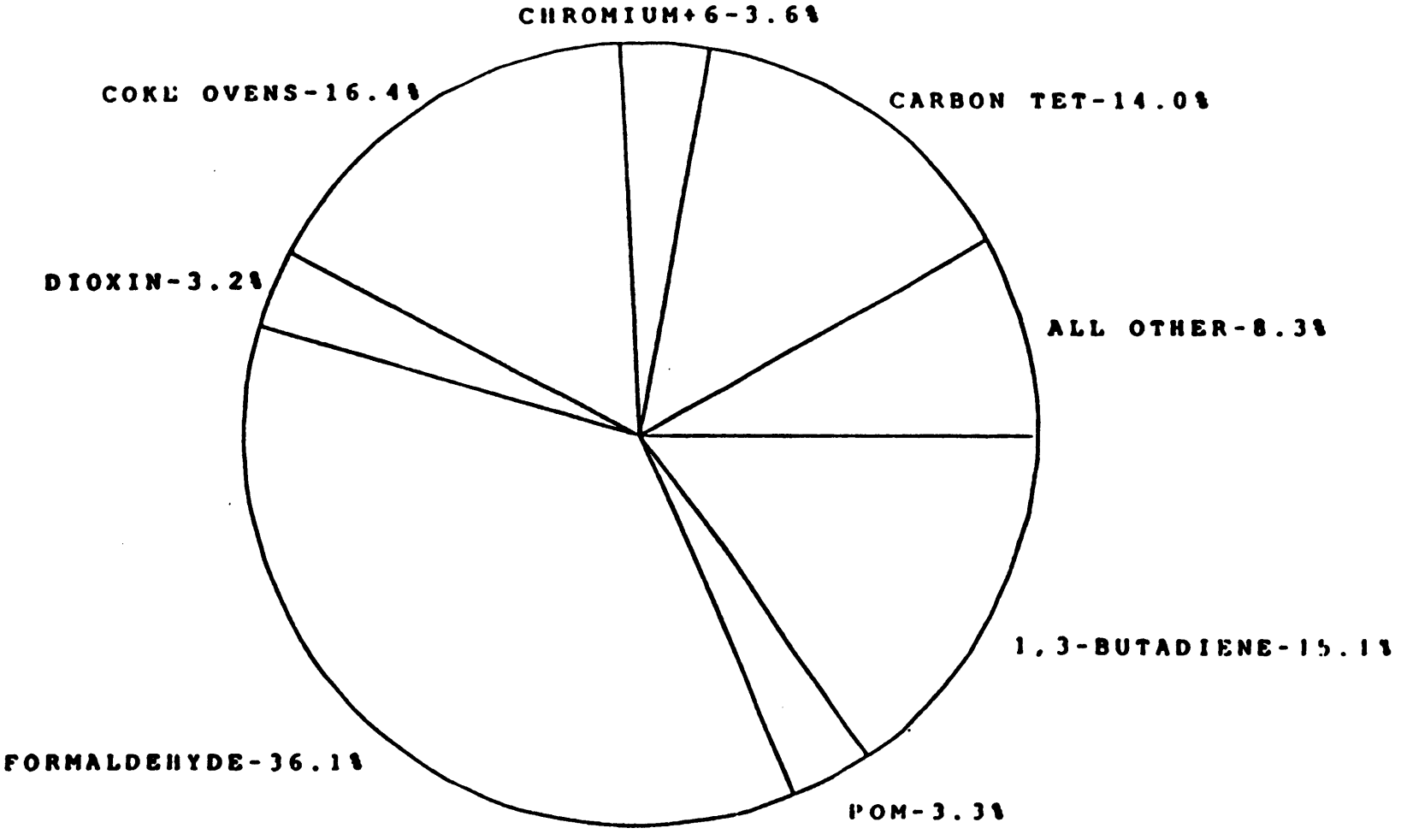
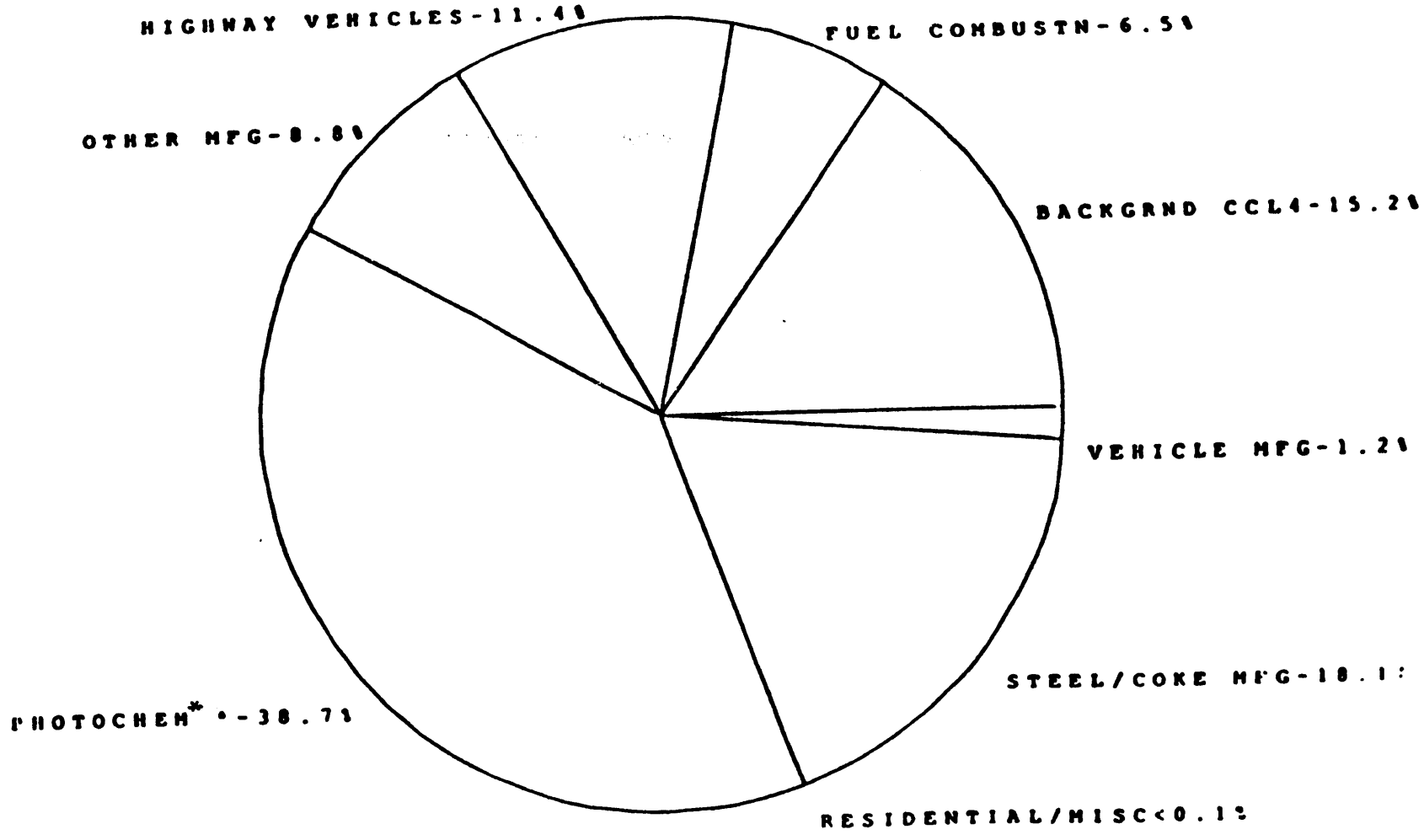


Figure 3-2. Estimated Excess 70-Year Incidence, Area Wide by Source Grouping Contribution



*PHOTOCHEMICAL GENERATION OF FORMALDEHYDE FROM EMISSIONS FROM VEHICLES, INDUSTRIAL FACILITIES, AND MISCELLANEOUS AREA SOURCES

Table 3-15. Pollutant Contribution to Risk at Grid Cell with Highest Individual Risk*

Pollutant	%
Coke oven emissions	37.4
Formaldehyde	24.6
1.3 butadiene	11.9
Carbon tetrachloride	9.4
Arsenic	2.8
Chromium	2.6
POM	2.6
Dioxins	2.6
Beryllium	2.0
Asbestos	1.3
Benzene	1.2
Gasoline vapors	0.6
Cadmium	0.5
Benzo(a)pyrene	0.1
Ethylene dibromide	0.1
Vinyl chloride	0.1
Trichloroethylene	0.1
Others**	0.1
TOTAL	100.0

*Grid Cell 136.

**Perchloroethylene, PCBs, chloroform, styrene, acrylonitrile, ethylene oxide, methylene chloride, chlordane, heptachlor, and epichlorohydrin.

Table 3-16. Source Grouping Contribution to Grid Cell with Highest Individual Risk

Source Grouping[••]	%
Steel and coke manufacturing	40.5
Photochemically generated formaldehyde	26.8
Background carbontetrachloride	10.6
Highway vehicles	9.1
Other industry	6.8
Fuel combustion	5.1
Vehicle manufacturing	1.1
TOTAL	100.0

[•] Grid cell 136.
[••] Residential and miscellaneous sources contribute less than 0.1%.

Limitations: One strength of this study is the number of pollutants that were analyzed (27 carcinogenic and 15 non-carcinogenic) relative to the other studies. The pollutants that were analyzed also cover those pollutants that cause the highest increased cancer incidence in the other studies. A weakness of the study was that it did not break down the sources associated with each pollutant. What is presented are two breakdowns: (1) a breakdown of total risk by individual pollutants, and (2) a breakdown of total risk by source groupings. The other studies segregated individual pollutants by their sources. While the study does account for background levels of carbon tetrachloride and formaldehyde, it does not account for background levels of any other pollutants [most other studies don't either] or for in-migration of pollutants from other areas. The study also does not segregate formaldehyde concentrations between background levels and those levels produced by the sources.

Another weakness of the study involves the use of the ISCLT model for modeling area sources. Ambient concentration estimates from ISCLT may be less than the estimates of the Climatological Dispersion Model (CDM) by a factor of two or more under some assumptions.

Many of the general assumptions and limitations itemized in Section 2.5 apply to this study.

3.4 The Houston Study[11]

Report Title/Date: A Risk Assessment Based Air Enforcement Strategy for Harris County, Texas, 1988

Conducted by: U.S. EPA Region 6

Background and Methodology: The purpose of this study was to provide insight into the process of assessing the health impacts of chemical compounds in developing effective compliance/enforcement efforts using existing regulations. Harris county was selected because it contains Houston, Texas, the fifth most populated city in the U.S. Immediately adjacent to downtown Houston is the Houston Ship Channel which contains hundreds of companies that comprise what has been termed the largest petrochemical complex in the world. Thus, the study area has the potential for the greatest impact of chemical compounds on the largest population within EPA Region 6 and possibly the entire U.S.

The emissions inventory of air pollutants for Harris County was examined with respect to five groups of source categories. The five categories are Texas Air Control Board (TACB) permitted point (stack) sources, TACB permitted fugitive (area) sources, small non-permitted and area sources, mobile sources, and accidental releases. The TACB emissions inventory has generally been developed and maintained in terms of non-methane volatile organic compounds (VOC) emissions for permitted sources. VOC emissions were speciated based on speciation factors associated with the Source Classification Code (SCC) of the individual emission point. The individual chemical compounds examined for this study are the chemical compounds defined as hazardous, extremely hazardous, or toxic chemical substances in Title III Sections 302 and 313 of the Superfund Amendments and Reauthorization Act (SARA), the Resource Conservation and Recovery Act (RCRA), and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), or any amendments to these acts. The compounds considered as having the greatest potential for putting the population at risk were then selected for dispersion modeling and a risk assessment study.

All permitted (both stack and fugitive) sources within a 20 mile radius of the center of the ship channel were evaluated. The speciation of the permitted point sources resulted in 35.1 percent of the VOC emissions being classified into individual chemical compounds. The speciation of the permitted fugitive sources resulted in 37.2 percent of the VOC emissions being classified into individual chemical compounds.

The categories examined for non-permitted area sources included: emissions from architectural coatings, automobile refinishing, consumer solvents, cutback asphalt operations, degreasing operations, drycleaning, fuel combustion, gasoline transfer, graphic arts operations, and solid waste disposal. The speciation of the non-permitted area sources resulted in 37.2 percent of the VOC emissions being classified into individual chemical compounds.

The mobile emissions inventory included categories of aircraft, automobiles, railways, and vessels. The EPA National Emissions Data System (NEDS) which utilizes the Mobile 3 model was used to calculate the mobile emissions. Standard emission factors were then applied to the mobile emissions which resulted in 28.9 percent of the VOC emissions being classified into individual chemical compounds.

The TACB requires that all permitted facilities report air pollutants emitted outside of the normal course of operations. These emissions are generally associated with plant start-ups, shut-downs, maintenance operations, and upsets. These upset reports for TACB were examined for the period June 1985 through May 1986 to determine the magnitude and frequency of the accidental releases from permitted facilities in the area. There were 1,372 upsets reported for this time period but only 307 of the reports contained data sufficient to quantify emissions. It appears that emissions from upsets may be greatly underestimated for this study.

The compounds selected for dispersion modeling were butadiene, methyl chloride, benzene, formaldehyde, toluene, and xylene. Toluene and xylene are not carcinogenic and have no unit risk factors associated with them so they are omitted from further discussion. The model employed was the Industrial Source Complex Model in its long term mode (ISCLT). The results represent the annual average concentrations. Receptors were selected at census tract centroids so that the number of people exposed to the annual concentrations were known. Unit risk factors were applied to each predicted annual concentration for each chemical modeled to yield the upper bound number of cancer cases for each of the 182 receptor areas. The unit risk factors employed for benzene, butadiene, formaldehyde, and methyl chloride were 8.3E-6; 2.8E-4; 1.3E-5; and 3.6E-6 lifetime risk per ug/m*3, respectively. The modeling was conducted for each source category so that the predicted cancer cases could be compared by source category for each chemical.

Results: Table 3-17 presents the predicted excess cancer cases for the study assuming a population of 2,055,066. As can be seen from the table, butadiene is associated with the highest predicted excess cancer incidence. Fugitive sources are associated with the highest predicted excess cancer incidence.

Limitations: The most obvious limitation to this study is the limited number (4) of pollutants analyzed. Of the 11 studies whose risk analyses were reviewed, only one study examined fewer pollutants. The grouping of the source categories also limits the inferences that can be made towards the effects that specific source categories have on increased cancer incidence.

Table 3-17. Upper Bound Annual Predicted Cancer Cases in Harris County for a Population of 2,055,066

Source Category	Benzene	Butadiene	Form-aldehyde	Methyl Chloride	Total
Point Sources TACB Permits	.031	.139	.060	.004	.234
Point Sources Speciated VOC	.017	-	.072	.00038	.089
Fugitive Sources TACB Permits	.013	1.682	.002	.020	1.716
Fugitive Sources Speciated VOC	.015	.047	.569	.003	.634
Small Area Sources Non-Permitted	.00021	-	.00013	-	.00033
Mobile Sources	.0023	-	.0047	-	.0071
TOTAL	.078	1.867	.708	.027	2.681

Actual Cancer Mortality in Harris County (1985) is 3,422

The use of SCC profiles and VOC speciation profiles has several weaknesses in that they under-represent many chemical manufacturing operations; they do not include many less common but potent substances; they do not address metals; and speciation profiles are not considered the best approach for estimating air toxics emissions. It also appears that emissions from spills and accidental releases may be under-represented due to the limited data that were good enough to estimate emissions from these episodes.

It was emphasized throughout this report that the findings, and the analysis in general, were strictly preliminary. It was concluded that the emissions inventory of the individual chemical compounds, as used in the study, was only of a preliminary nature. The compilation of a more accurate inventory by both the reporting facilities and the TACB is needed in order to perform a more definitive risk assessment.

Many of the general assumptions and limitations itemized in Section 2.5 apply to this study.

3.5 The Twin-City Study[17]

Report Title/Date: Estimation and Evaluation of Cancer Risks from Air Pollution in the Minneapolis/St. Paul Metropolitan Area, March 1992

Conducted by: Minnesota Pollution Control Agency, Air Quality Division

Background and Methodology: The purpose of this study was to analyze sources of air pollutants suspected or known to cause cancer, and to estimate the health risk from exposure to these pollutants. The study was designed to estimate and characterize emissions of these selected pollutants, and to model the resulting human health risk.

The study area consisted of two overlapping sections -- the source area and the receptor area. In an attempt to include all major sources of toxic air pollutants, a source area much larger than the receptor area was defined. The receptor area population was estimated at 1,227,584. In order to use air dispersion modeling the study area was divided into a 1 km by 1 km square grid system.

Table 3-18 lists the carcinogenic pollutants inventoried and the unit risk factors associated with each pollutant. These are air pollutants for which dose-response relationships for carcinogenicity have been estimated by the U.S. EPA. It should be noted that because there were no monitoring data available for this study, background concentrations of pollutants (e.g., carbon tetrachloride) and secondary formation of pollutants (e.g., formaldehyde) are not considered in this study.

The emissions inventory consisted of point sources, area sources, and mobile sources. For the purposes of this study, only larger sources with adequate emissions point information were treated as point sources. Specifically, facilities with data from EPA's National Emissions Data System (NEDS) or that reported emissions to EPA's Toxic Release Inventory (TRI) were treated as point sources. One hundred eighty one (181) facilities were included in the database.

Emissions data from TRI was considered superior to NEDS emissions data. If a facility had TRI emissions data, these data were used as reported (because the emissions are compound specific). The NEDS database consists of criteria emissions data. Use of NEDS entailed speciating the reported

Table 3-18. Pollutants Included in Inventory and Their Unit Risk Estimates

I. CARCINOGENS

URE*	CAS	COMPOUND	WEIGHT OF EVIDENCE
2.2E-6	75-07-0	ACETALDEHYDE	B2
6.8E-5	107-13-1	ACRYLONITRILE	B1
4.3E-3	7440-38-2	ARSENIC	A
8.3E-6	71-43-2	BENZENE	A
1.7E-3	50-32-8	BENZO(a)PYRENE (BaP)	B2
2.4E-3	7440-41-7	BERYLLIUM	B2
2.8E-4	106-99-0	1,3-BUTADIENE	B1
1.8E-3	7440-43-9	CADMIUM	B1
1.5E-5	56-23-5	CARBON TETRACHLORIDE	B2
2.3E-5	67-66-3	CHLOROFORM	B2
1.2E-2	7440-47-3	CHROME-6	A
6.2E-4		COKE OVEN EMISSIONS	A
2.6E-5	107-06-2	1,2-DICHLOROETHANE (Ethylene Dichloride)	B2
5.0E-5	75-35-4	1,1-DICHLOROETHYLENE (Vinylidene Chloride)	C
1.2E-6	106-89-8	EPICHLOROHYDRIN	B2
2.2E-4	106-93-4	ETHYLENE DIBROMIDE	B2
1.0E-4	75-21-8	ETHYLENE OXIDE	B1
1.3E-5	50-00-0	FORMALDEHYDE	B1
6.6E-7		GAS VAPORS (MARKETING)	B2
4.9E-4	118-74-1	HEXACHLOROBENZENE	B2
4.7E-7	75-09-2	METHYLENE CHLORIDE	B2
0.0E-0		NICKEL**	A
5.8E-7	127-18-4	PERCHLOROETHYLENE (Tetrachloroethene)	B2
1.7E-3		POLYCYCLIC ORGANIC MATTER (POM)	
3.7E-6	75-56-9	PROPYLENE OXIDE	B2
5.7E-7	100-42-5	STYRENE	B2
3.3E+1	1746-01-6	2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN	B2
1.7E-6	79-01-6	TRICHLOROETHYLENE	B2
4.1E-6	75-01-4	VINYL CHLORIDE	A

II. CARCINOGENS USING COMPARATIVE POTENCY FOR POM

URE*	SUBSTANCE
3.0E-5***	- DIESEL PM
2.9E-4***	- GASOLINE PM
1.0E-5***	- WOOD STOVE PM

*URE = UNIT RISK ESTIMATE (LIFETIME RISK/UG/CUBIC METER) (the probability of contracting cancer as the result of constant exposure over 70 years to an ambient concentration of 1 microgram per cubic meter)
**URE for Nickel is listed as 0.0 E-0 because it is assumed in this study that none of the nickel emitted is in the carcinogenic refinery dust or subsulfide forms.
***PARTICLE UNIT RISK ESTIMATE (LIFETIME RISK/UG/CUBIC METER)

VOC emissions data into specific pollutants. The species profiles employed were obtained from the U.S. EPA's Air Emissions Species Manual, Volume I and Volume II.

Three other sources of data were used in the analysis of point sources. These included: emissions data from the Ford Motor Company Twin Cities Assembly Plant; survey data on ethylene oxide from local hospitals; and emissions test data from the Hennepin Energy Resource Corporation. These source specific data were considered superior over both the NEDS and TRI data.

The area source inventory also consisted of estimating emissions and identifying locations. Emissions were estimated based on information from a variety of sources (e.g., emission factors and employment data for specific Standard Industrial Classification [SIC] codes). The emissions were then assigned a location. Generally the emissions estimates resulted in area wide or county wide emissions values, which were subsequently allocated to census tracts.

Mobile source emissions were estimated using MOBILE4 and then speciating the results. MOBILE4 calculates the emissions of hydrocarbons, carbon monoxide, and nitrogen oxides from gasoline fueled and diesel highway motor vehicles. The emissions estimates are dependent upon a variety of area-specific conditions such as ambient temperature, speed, and mileage accrual rates.

The emissions inventory process resulted in approximately 37 million pounds/year of carcinogens. Figures 3-3 and 3-4 show the breakdown of the total emission inventory by source type and pollutant respectively.

Two dispersion models were used in this study -- the Industrial Source Complex-Long Term (ISCLT) for point sources, and Climatological Dispersion Model (CDM) for area and mobile sources. The receptors in this study were defined as the centroids of the census tracts within the modeling area for all source types. There were 366 census tracts in the source area and 284 in the receptor area. The dispersion modeling resulted in area-wide, upper-bound risk estimates.

The risk assessment for this study was limited to cancer effects. Risk at a particular census tract was estimated by multiplying the modeled concentration of individual pollutants times the unit risk factor for that pollutant and summing for all pollutants. Excess cancer incidence at a census tract was then calculated by multiplying the individual risk by the population of the census tract. It follows that excess cancer incidence for the entire study is the sum of the excess cancer incidence for each of the census tracts.

Results: This study estimates 222 excess cancer cases over a 70 year period in the receptor area for the pollutants and sources studied. This translates to slightly over three excess cancer cases per year for the receptor area. The average population risk is the total excess cancer incidence (222) divided by the population (1.2 million) and divided by the 70 years of assumed exposure. This results in an population risk of 2.64 excess cancer cases per year per million residents. The area wide individual lifetime risk is the total excess cancer incidence (222) divided by the population (1.2 million). This results in 1.84E-04 chance of an individual developing cancer in their lifetime from continuous exposure to the air pollutants studied.

Figures 3-5 and 3-6 show the breakdown of total cancer incidence by source category and specific pollutant, respectively. As can be seen in Figure 3-5, road vehicles are attributable for 61

Figure 3-3. Sources of Carcinogenic Pollutant Emissions in the 7-County Twin Cities Metropolitan Area

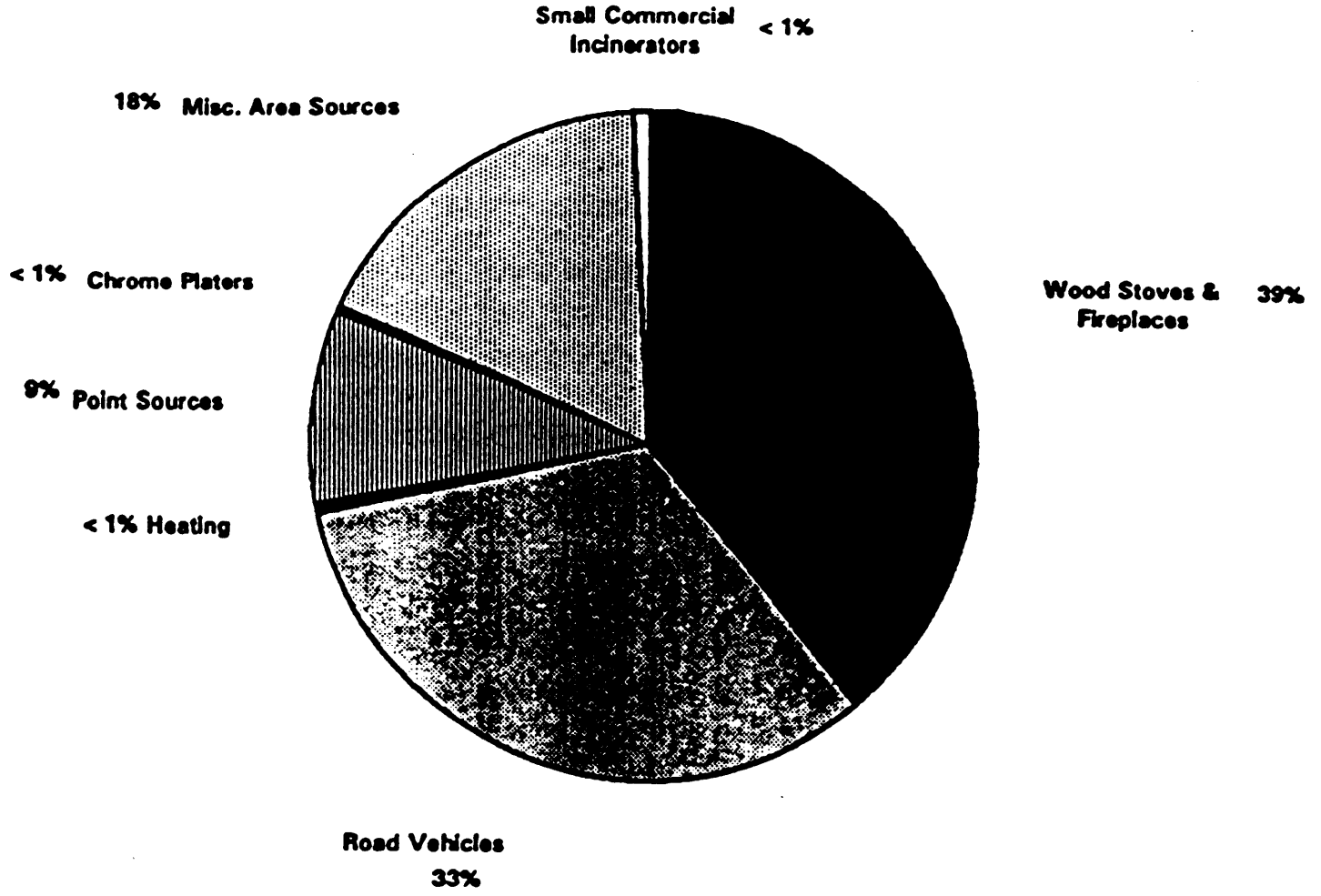


Figure 3-4. Emissions of Carcinogenic Pollutants in the 7-County Twin Cities Metropolitan Area

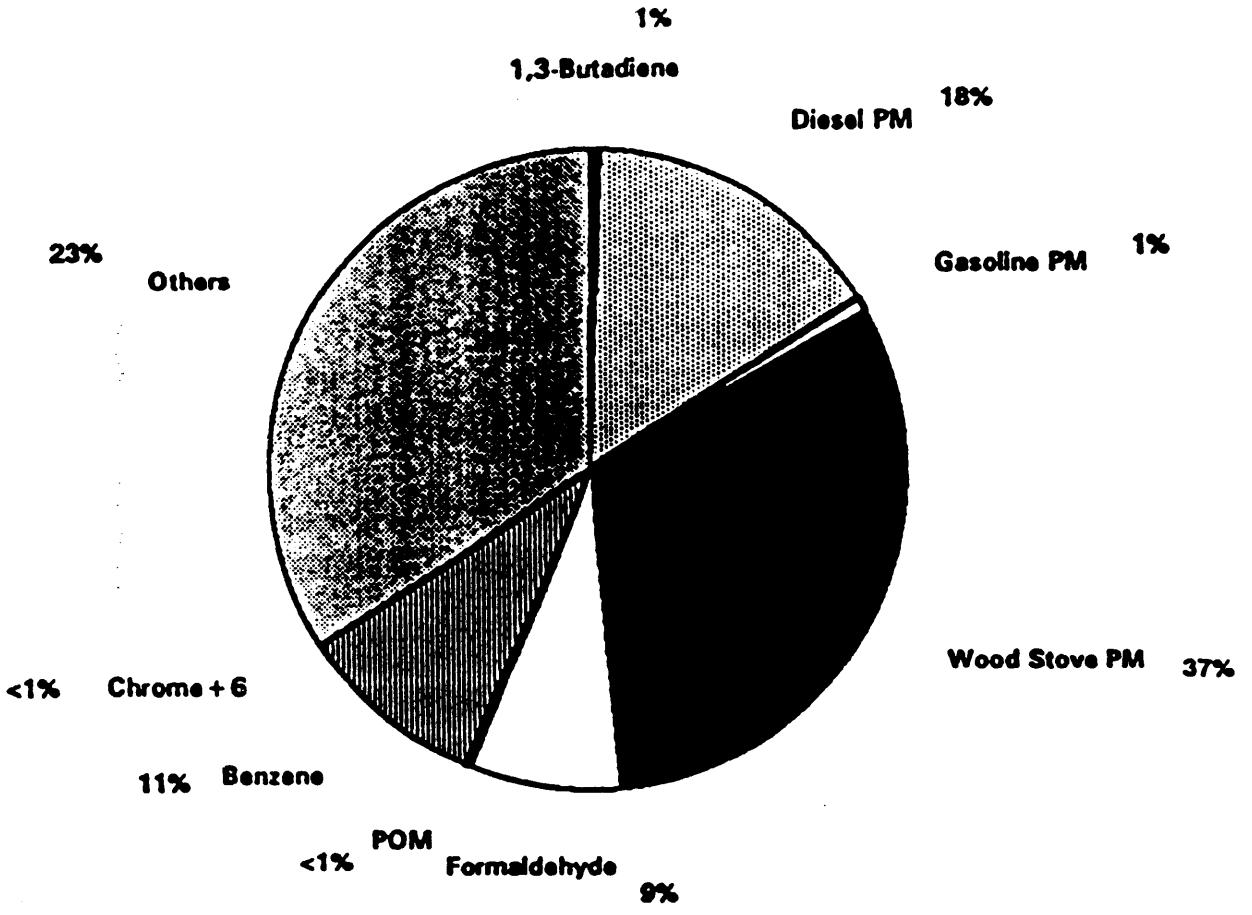
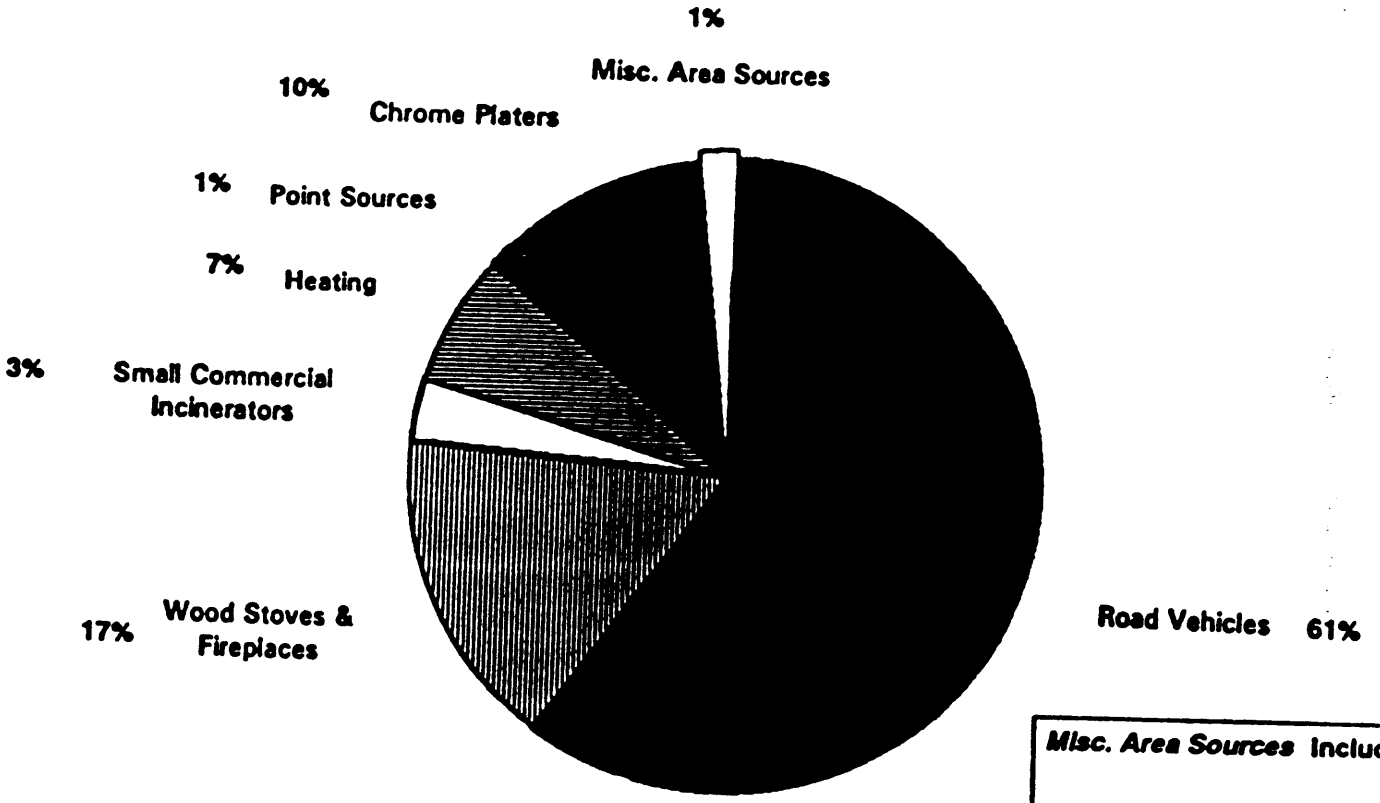


Figure 3-5. Estimated Excess Cancer Incidence by Source Category

Total Estimated Excess 70 Year Cancer Incidence = 222 = 2.64
Excess Cancer Cases/Year/Million Population in Receptor Area

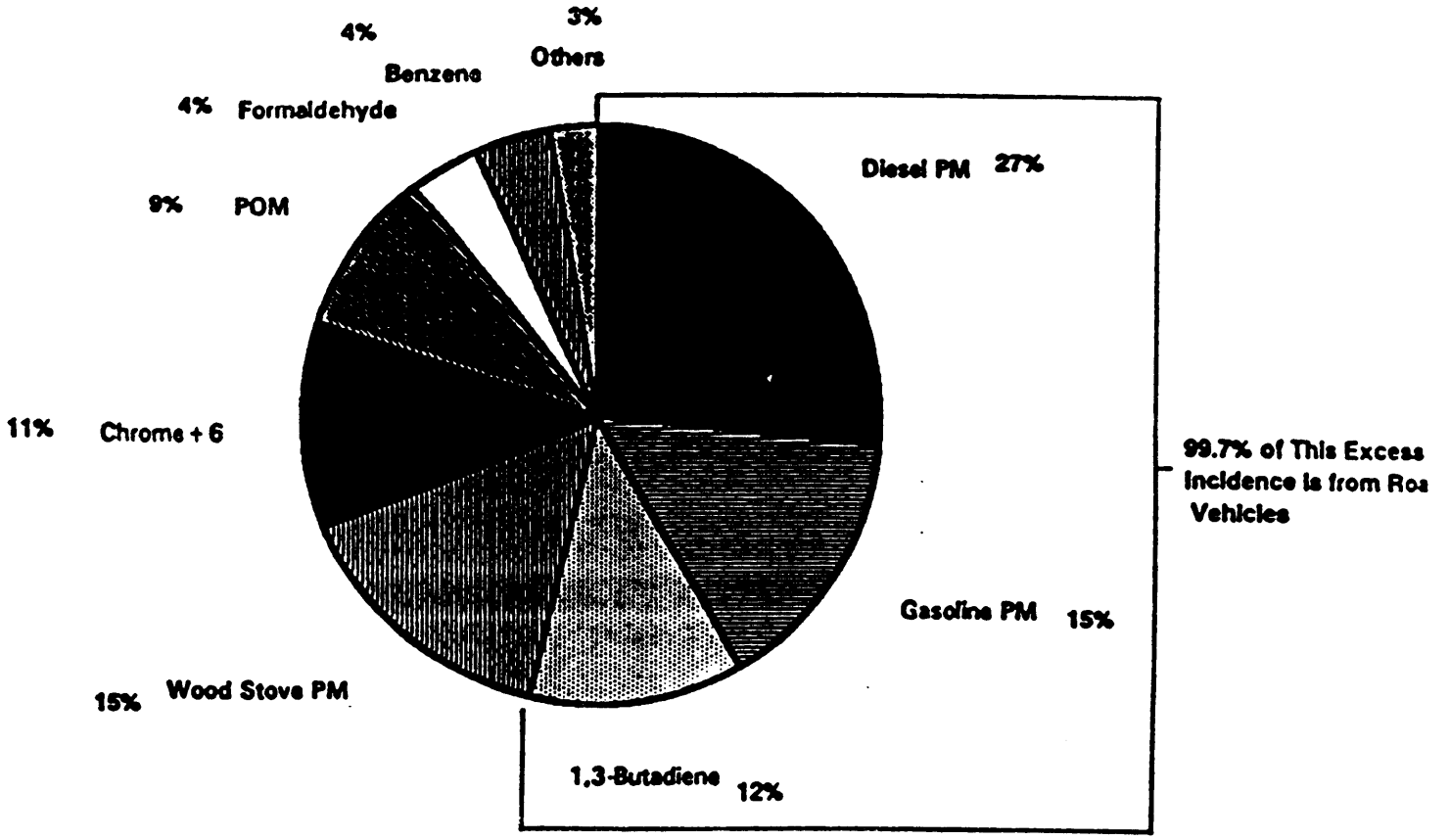


Misc. Area Sources **Includes:**

o Comfort Cooling Towers	37%
o Degreasing	26%
o Small Hospitals	16%
o Gas Marketing	6%
o Industrial Cooling Towers	6%
o Research Labs	5%
o Dry Cleaners	1%
o Solvent Usage	1%
o Surface Coating	1%
o Waste Oil Burning	1%

Figure 3-6. Estimated Excess Cancer Incidence by Pollutant

Total Estimated Excess 70 Year Cancer Incidence = 222 = 2.64
Excess Cancer Cases/Year/Million Population in Receptor Area



percent of excess cancer incidence. The next most important source is woodstoves/fireplaces with 17 percent of excess cancer incidence.

The pollutants contributing the most to excess cancer incidence are diesel particulate, gasoline particulate, and woodstove particulate, contributing 27 percent, 15 percent, and 15 percent respectively. This cancer incidence is associated with the polycyclic organic matter (POM) fraction of the particulate.

Limitations: The strengths of this study include the number, and type, of pollutants and source categories that were analyzed. The results of the study fall within the range of results obtained from other, similar studies.

One weakness of the study was the fact that secondary formaldehyde and background carbon tetrachloride were not considered. Inclusion of these pollutants could increase the estimated excess cancer incidence for the study. Another weakness is the use of speciation factors for extrapolating air toxics emissions from VOC or particulate emissions.

Many of the general assumptions and limitations itemized in Section 2.5 apply to this study.

3.6 The Texas Study[16]

Report Title/Date: An Assessment of the Urban Air Toxics Problem in Texas; June 1989 (second draft)

Conducted by: Texas Air Control Board (Now called the Texas Natural Resources Conservation Commission), Research Division

Background and Methodology: This project was designed to be a screening effort using available data sources to evaluate impacts from both point and area sources in two areas: Dallas-Fort Worth and the Houston area, in Texas. It used computer models to predict ground level concentrations of and assess public exposure to a selected list of compounds the potential health effects of which were of concern. Results were analyzed to identify areas with predicted excessive exposures. Ambient data for air toxics was also analyzed to identify any areas with monitored levels considered excessive. In some cases, it possible to compare modeled and monitored levels to estimate the relative contribution of point sources to the urban exposure. The adequacy of the available data bases and the effectiveness of the agency's air toxics strategy were also reviewed.

The Houston area is highly industrialized, including one of the world's largest concentration of petrochemical and related chemical process industries. Along the Gulf Coast a large fraction of the nation's basic petrochemicals is produced. The Houston area has a strong thermal mixing of its atmosphere and almost continuous low level winds, providing effective dilution.

Dallas-Fort Worth is less industrialized than Houston with approximately 3000 manufacturing plants making apparel, building material, food, oil field supplies, electronic and other products. Fort Worth has a diversified urban economy with aircraft, foods, mobile homes, electronics, chemicals and plastics among the products of its over 1100 plants.

Ambient monitoring data in Houston (extensive) and Dallas-Fort Worth (sparse) were reviewed and compared with TACB's effects screening levels for each compound detected. TACB screening levels for chronic exposure are typically based on 0.1 percent of the most appropriate occupational exposure limit or on other toxicity information. Review of the monitoring data revealed that several compounds were detected at concentrations that significantly exceeded the applicable screening levels.

Assessing the impact of emissions from point sources consisted of 3 steps: describe the population distribution in each county, estimate annual average ambient concentrations using dispersion modeling, and use the calculated concentrations with the population data to calculate population exposure.

Results - Dallas/Fort Worth: Of the four compounds assessed in Dallas County, 3 were modeled or measured at concentrations of potential concern: asbestos, chromium and benzene. Modeled asbestos levels of up to 0.009 ug/m^3 were predicted, a 3-fold exceedence of the TACB annual effects screening level for asbestos. Benzene levels of 2.5 ppb (annual average) were model-predicted, a 3-fold exceedence of the effects screening level, representing the highest potential risk of the compounds studied. Area sources (motor vehicles, solvent use, etc.) were found to be mostly responsible for ambient benzene levels. Modeling of chromium levels in residential areas adjacent to two sources predicted maximum annual concentrations in the range of 0.1 to 0.5 ug/m^3, which is up to a 20 fold exceedence above screening levels if all is assumed to be hexavalent in form. The screening level is still exceeded, but by only 4 fold, if the chromium is assumed all trivalent. The report authors state that most ambient chromium should be assumed to exist in the trivalent state. Styrene was also considered, but model predictions indicate no possibility of levels exceeding screening levels, and styrene is not detected in NMOC ambient sampling done in Dallas-Fort Worth. The results are in Table 3-19 and summarized in Table 1-5 in Chapter 1.

Results - Houston/Harris County: The results of human exposure modeling were examined to evaluate maximum predicted concentrations due to point sources and total inhaled dose. In addition, dispersion modeling was conducted and the grid output examined to compare the concentrations predicted to occur at the receptor nearest each of seven ambient monitoring stations. The predicted versus measured concentrations are compared in Table 3-20 to give an idea of the relative contribution of point sources to ambient concentrations in Harris County.

The results are summarized in Table 3-19. Of the pollutants considered, benzene, formaldehyde, allyl chloride, acrylonitrile and ethylene dichloride exceed or equal the respective significance levels, in order of extent of exceedence. For benzene, as in Dallas-Fort Worth, mobile and other area sources are implicated as major contributors to ambient benzene levels. Regarding formaldehyde, the study authors surmise that area sources and atmospheric reactions are perhaps more important contributors to ambient formaldehyde than point sources, but this can not be adequately assessed because of errors in the data base. Model-predicted allyl chloride levels were up to three times the screening level, whereas ambient allyl chloride was detected at only one site at a level 4 times lower than model-predicted. No clear conclusions were drawn concerning allyl chloride other than improved emissions data are needed. Dispersion and population modeling of acrylonitrile predicted annual averages in residential areas adjacent to point sources at a level four times the effects screening level. A comparison of predicted versus measured concentrations for three monitoring studies is shown in Table 3-20. The report recommended that sampling be done near the major

Table 3-19. Results of the Texas Urban Air Toxics Assessment

Location	Compound Evaluated	Monitored or Predicted Levels of Concern (ug/m^3)	Factor of Exceedance of ESL	Recommended Action
Dallas County	asbestos	.009 (P)	3	ascertain that emissions are occurring, ambient monitoring
	benzene	8 (M)	3	continued monitoring, better characterization of sources
	chromium	0.1-0.5 (P)	4-20*	ascertain that emissions are occurring, ambient monitoring
	styrene	<ESL		
Harris County	acrylonitrile	10-20 (P)	2-4	
	benzene	19 (M)	6	
	carbon tetrachloride	<ESL		
	chloroprene	<ESL		continued monitoring
	allyl chloride	3-10 (P)	3	ascertain that emissions are occurring
	ethylene dichloride	4.7 (M)	1	
	formaldehyde	7 (M)	4.5	ascertain that emissions are occurring, better characterization of sources
	epichlorohydrin	<ESL		
	ethylene oxide	<ESL		

M = monitored P = predicted <ESL = below effects screening level
* the ESL for Cr III is four time higher than the ESL for Cr VI

Table 3-20. Predicted Versus Measured Concentrations of Compounds Evaluated in Harris County (ug/m^3)

	SAMPLING STATION													
	HRM 1		HRM 3		HRM 4		HRM 7		HRM 8		TAMS		UATMP	
COMPOUND	P	M	P	M	P	M	P	M	P	M	P	M	P	M
acrylonitrile	.1	<LLD	.06	<LLD	.01	<.66	.01	<LLD	.02	<.66	.04	NI	.05	NQ
benzene	.4	15	.6	14	.3	9	.2	8	.4	19	.5	7	.4	4.5*
carbon tetrachloride	.3	<LLD	3-10	<3	.3	<LLD	.1	<LLD	.1	<LLD	.4	1.3	.8	NI
chloroprene	.4	NQ	.02	NQ	.01	NQ	.006	NQ	.01	NQ	.02	NI	.04	1.6
allyl chloride	.2	NQ	1.0	NQ	.4	NQ	.1	NQ	.2	NQ	1.3	.35	.4	NI
ethylene dichloride	.6	<2	.5	<2	.2	<2	.1	<2	.2	<2	.5	1.6	.4	4.7*
formaldehyde	.4	NQ	2.0	NQ	1.0	NQ	.2	NQ	.2	NQ	.5	NI	1.4	NI

M = measured concentration at a particular sampling station
P = concentration predicted by air dispersion modeling to occur at the location of the sampling station
<LLD = below lower limit of detection
NI = not included in study
NQ = not quantified (speciated)
* = may not represent entire concentration since analytical technique did not allow complete separation of benzene from 1,2-dichloroethane.

HRM = Houston Regional Monitoring Network
TAMS = Toxic Air Monitoring System (EPA)
UATMP = Urban Air Toxics Monitoring Program

acrylonitrile source to determine the actual public exposure. For ethylene dichloride, human exposure modeling predicted maximum exposures in the range of 3 to 10 ug/m^3, whereas the highest measured concentration was 4.7 0 ug/m^3, a slight exceedence of the screening level. Measured concentrations, as shown in Table 3-20, are up to an order of magnitude higher than predicted by modeling at the sampling site. Either other sources are implicated or point source emissions were under-reported. In either case, the concentrations were not high enough to be of concern to the report authors.

Modeling/monitoring results show levels of carbon tetrachloride, chloropene, epichlorohydrin, and ethylene oxide below screening levels, as shown in Table 3-19. The results from these studies are summarized in Table 1-5.

Limitations: The emission inventory data bases used in this study were acknowledged to very weak for area sources. Assessment of the area source contribution could only be inferred through examination of ambient air monitoring data. Point/area source cutoffs were not specified in the report.

Many of the general assumptions and limitations itemized in Section 2.5 apply to this study.

3.7 The EPA Noncancer Screening Study[13-15]

Report Title/Date: Toxic Air Pollutants and Noncancer Health Risks: Screening Studies. External Review Draft.

Conducted by: EPA's Office of Air Quality Planning and Standards, Research Triangle Park, NC, 27711. September 1990.

Background and Methodology: Two screening studies were conducted within the context of this study to characterize the potential noncancer risks associated with exposure to toxic air pollutants, each looking at slightly different aspects of the question. Each was conducted by comparing modeled and/or monitored ambient concentrations to health reference (HRLs) levels and lowest-observed-adverse-effect levels (LOAELs). [In this context, a LOAEL is the lowest dose or exposure level at which a statistically or biologically significant effect is observed in the exposed population. A HRL is the LOAEL divided by appropriate uncertainty factors to account for inter- and intra-species variability and the use of a LOAEL rather than a no-observed-adverse-effect level (NOAEL).]

The first study was a national "broad screening study" which examined exposure to single or multiple pollutants in ambient air based on exposure data inferred from ambient monitored pollutant levels or emissions-modeled data from many areas of the country. Exposure data was based on measured ambient concentrations for approximately 325 pollutants monitored throughout the U.S. and modeled annual average ambient concentrations for approximately 40 pollutants emitted from more than 3,500 facilities. Health data and quantitative exposure data were available for approximately 150 pollutants.

The second study involved a more detailed evaluation of a midwestern industrialized urban county. This analysis expanded the number of chemicals evaluated in the broad screening study and assessed the combined impact of multiple emission sources versus the impact of sources, singly. Approximately 200 chemicals emitted from 122 point sources plus 9 area sources were evaluated.

Health reference levels and LOAELs were compared to modeled pollutant concentrations in three independent modeling exercises.

Results - Broad Screening Study: For those few chemicals with both health and exposure data, noncancer health risks appeared to be of concern. For approximately half of these chemicals, modeled and/or monitored levels exceeded health reference levels at numerous sites throughout the country. Ambient levels for approximately one-third of these chemicals exceeded the health reference level at more than 25 percent of the sites studies. These exceedences were associated with both short-term and long-term ambient monitored and long-term modeled concentrations. Modeling of short-term emissions was not performed because of data limitations. Less than 5 percent of the sites and chemicals indicated ambient concentrations exceeding LOAELs.

The results of the broad screening study are summarized in Table 1-5 in Chapter 1 of this report. The HAPs ranking of highest potential concern based on potential exceedences of HRLs at 25 percent or more of observed sites are (in no relative order or ranking): acetaldehyde, acrolein, arsenic, benzene, beryllium, carbon disulfide, carbon tetrachloride, chloroform, ethylene oxide, formaldehyde, hydrogen sulfide, methyl ethyl ketone, methyl methacrylate, methyl isocyanate, nitrobenzene, perchloroethylene, phenol, phthalic anhydride, styrene, tetramethyl lead, toluene diisocyanate, and vinyl chloride.

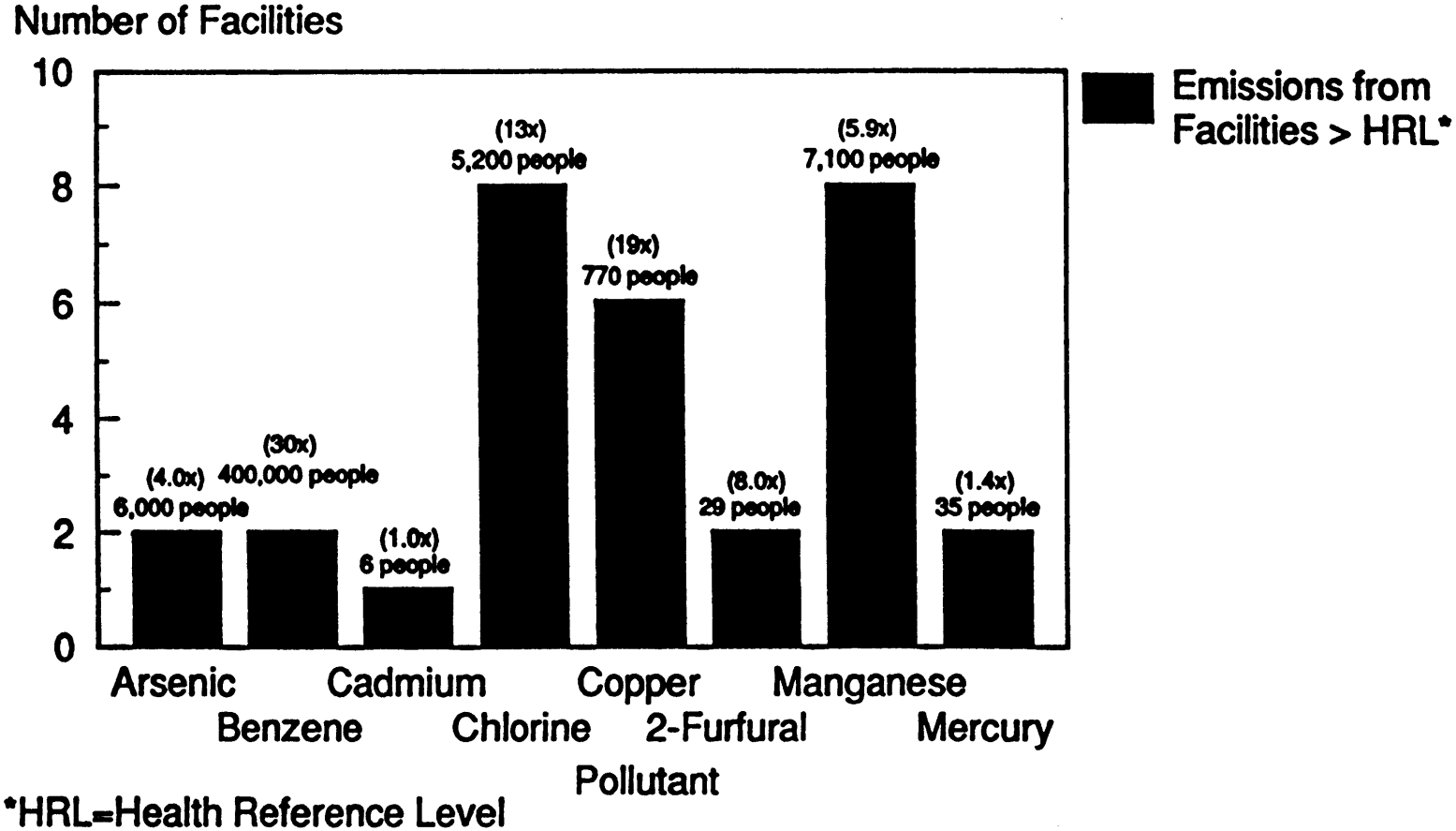
Because of the considerable uncertainty in the data sets used in this noncancer analysis, and because of the difficulty in comparing noncancer endpoints, the pollutants are not ranked in this study. In addition, it is unclear how to interpret the effects of a pollutant concentration slightly above a specific health effects level.

Results - Urban County: Results suggested that a larger number of pollutants exceeded health reference levels for short-term modeled concentrations than for long-term modeled concentrations. Ambient concentrations were estimated to exceed health reference levels for long-term concentrations predicted by EPA's Industrial Source Complex Long-Term Model (ISCLT) and the Human Exposure Model (4 and 8 percent of pollutants, respectively) and short-term (24 hour) concentrations predicted by the SCREEN Model (22 percent of pollutants). Estimated long-term concentrations did not exceed any pollutant LOAELs. Estimated short-term (24 hour) concentrations exceeded LOAELs for approximately 2 percent of the pollutants assessed. In general, proximity to individual sources was a significant factor in determining degree of potential exposure. Another important finding of this study was that the additive contribution for a single pollutant emitted from a variety of sources resulted in health reference exceedences over a broad geographic area.

The urban county study concludes that for certain pollutants, the combined impact of multiple sources may result in substantial exposure to many people. This finding suggests that the problem may not be limited to large point sources, but that smaller point sources and area sources that are numerous in populated areas cannot be ignored. Similarly, exposure to chemical mixtures may result in noncancer health impacts that might not be predicted if only impacts of individual pollutants are considered.

A listing of HAPs of highest potential concern based on the urban county modeling study are shown in Table 1-5 in Chapter 1 of this report. Two columns of pollutants are shown in Table 1-5, based on long-term and short-term modelled exposures, based on data from Figure 3-7 and Table 3-21, respectively. Those pollutants (not all of which are HAPs under Section 112) of potential concern

Figure 3-7. Results of Long-term (HEM) Modeling Analysis (Exposure from Individual Facility Emissions)



*HRL=Health Reference Level

Note: Factor in parenthesis denotes highest modeled estimate expressed as a multiple of the highest reference level.

Table 3-21. Urban County Study Results of Short Term (Screen) Analysis

Pollutant	Exceedance Factor for HRL*	Facilities	Exceedance Factor for LOAEL*	Facilities	Uncertainty Factor
Ethyl benzene	2.0	3			1,000
Formaldehyde	210	20	2	1	100
Heptane	14.0	6			100
Hexamethylenediamine	2.2	2			1,000
Hexane	1.7	1			100
Hexylene glycol	1.0	1			100
Lead	4.9	2	4.9	2	1
Methanol	1.7	3			100
Methyl cellosolve	2.6	1			1,000
Methyl ethyl ketone	85.0	36			100
Methyl methacrylate	1.5	1			100
o-Dichlorobenzene	1.1	1			1,000
o-Xylene	4.2	4			1,000
Phenol	1.8	1			1,000
Phthalic anhydride	1,700.0	32	1.7	3	1,000
Styrene	170.0	16			1,000
Sulfur	1.1	1			1,000
Toluene	5.7	9			1,000
Vinyl chloride	22.0	12			1,000
Xylene	50.0	32			1,000

*HRL=Health Reference Level, LOAEL=Lowest-Observed-Adverse-Effect Level

continued.....

Table 3-21. Urban County Study Results of Short Term (Screen) Analysis (continued)

Pollutant	Exceedance Factor for HRL*	Facilities	Uncertainty
1,1,1 Trichloroethane	5.5	2	1,000
2-Furfural	2.2	2	1,000
a-Pinene	35.0	3	1,000
Aectaldehyde	1.2	1	100
Acrolein	97.0	12	100
Acrylonitrile	8.4	3	100
Benzene	120.0	6	1,000
Butyl Cellosolve	17.0	16	1,000
Cadmium	13.0	6	1,000
Carbon sulfide	450.0	22	1,000
Cellosolve	1.8	1	1,000
Chlorine	440.0	31	1,000
Chlorobenzene	2.4	2	1,000
Chloroform	26.0	4	1,000
Chloroprene	110.0	14	1,000
Cyclohexanone	1.4	1	1,000
Cyclopentane	36.0	8	1,000
Dichlorotetrafluoroethane	820.0	22	1,000
Dimethyl Formamide	24.0	1	1,000
Ethyl acetate	180.0	42	1,000

*HRL=Health Reference Level

based on long-term exposures include: arsenic, benzene, cadmium, chlorine, copper, 2-furfural, manganese, and mercury. As is suggested by the projected HRL exceedance levels and number of persons exposed in Figure 3-7, benzene exceeds the respective HRL by the highest ratio (x30) and has the maximum number of people exposed (400,000). Some of the pollutants of greatest potential concern in the urban county study based on short-term exposures include: phthalic anhydride, carbon disulfide, chlorine, formaldehyde, styrene, benzene, chloroprene, acrolein and methyl ethyl ketone. All of the pollutants exceeding an HRL in this study because of projected short-term exposures are shown in Table 3-21 and Table 1-5 in Chapter 1.

Because of the considerable uncertainty in the data sets used in this noncancer analysis, and because of the difficulty in comparing noncancer endpoints, the pollutants are not ranked in this study. In addition, it is unclear how to interpret the effects of a pollutant concentration slightly above a specific health effects level.

Limitations: The sparseness of the available data represents the principal limitation of the screening studies. Few data were available to aid in the prediction of ambient concentrations and the derivation of health reference levels. Also, the contribution of mobile sources was omitted from the modeling analysis and the contribution of smaller point and area sources needed to be improved.

Many of the general assumptions and limitations itemized in Section 2.5 apply to this study.

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16. ABSTRACT

A number of screening studies are compiled and compared that assess exposures and risks from air toxics. Generally, these studies were based on dispersion modeling of air toxics emissions data. Cancer is the principal endpoint, although some noncancer endpoints are evaluated in the studies. This report is intended to provide background for development of EPA's national strategy to control urban area sources.

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